1995

Lighthouse Coal Bed Methane Project Environmental Assessment

United States Department of the Interior Bureau of Land Management

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U.S. Department of the Interior
Bureau of Land Management
Casper District Office

Buffalo Resource Area Office — Buffalo, Wyoming

Lighthouse Coal Bed Methane Project Environmental Assessment

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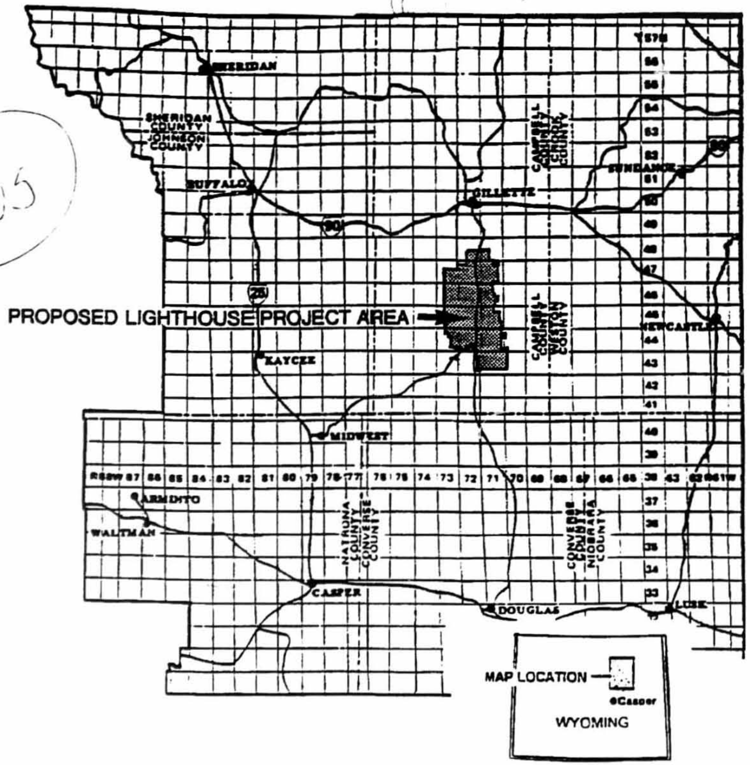

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United States Department of the Interior

BUREAU OF LAND MANAGEMENT
Buffalo Resource Area
189 North Cedar
Buffalo, Wyoming 82834

1792
Lighthouse CBM

MAR 3 1 1995

Dear Reader:

Enclosed is a copy of the environmental assessment (EA) for the American Oil and Gas Lighthouse Coal Bed Methane Project. Comments will be accepted until May 2, 1995. All substantive comments received will be taken into consideration before making a decision on whether or not to approve the proposed project. Comments should be sent to David Pomerinke, Area Manager, at the above address. After we have analyzed the comments we have received, a copy of the decision will be mailed to you. If you have any questions, please feel free to call Richard Zander in Buffalo at 1-800-301-3483.

Sincerely,

David A Pomerinke

David A. Pomerinke
Area Manager

Enclosure

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CHAPTER 1
PURPOSE OF, AND NEED FOR, THE PROPOSED ACTION

INTRODUCTION

American Oil and Gas Corporation (American), also doing business as Martens and Peck Operating, proposes a coal bed methane (CBM) project called the Lighthouse project near Gillette, Wyoming in central Campbell County just south of the Marquiss CBM project. Wells drilled in the project area would be from intermingled private, state, and federal oil and gas properties. At full production, American hopes to produce methane gas from a maximum of 200 wells completed in the Wyodak coal seam in the Lighthouse project area. Of the 200 wells, 100 would produce federally owned methane gas.

Drilling CBM wells on lands where the oil and gas rights are owned by the federal government must be done under an approved application for permit to drill (APD) issued by the Bureau of Land Management (BLM). In considering whether to approve the APDs for the Lighthouse Field, BLM must consider the possible project-specific and cumulative environmental impacts to assure compliance with the National Environmental Policy Act of 1969 (NEPA). This environmental assessment (EA) has been prepared to serve that requirement. An additional analysis will be completed at the time an APD is filed. This analysis will look at the site-specific impacts of the drilling location and its relationship to the cumulative impacts documented in this analysis.

PURPOSE AND NEED FOR THE PROPOSED ACTION

The purpose of the Proposed Action is to include federal oil and gas properties within the Lighthouse Field CBM project now being developed exclusively on state and private gas leases. Approximately 20 wells have been drilled, and nine are pending approval before the Wyoming Oil and Gas Conservation Commission (WOGCC). Approximately half of the CBM wells would be drilled on lands where the oil and gas rights are privately owned or owned by the state of Wyoming. American estimates that as many as 100 wells could be drilled on federal oil and gas leases. Drilling wells under an approved APD is the only way to determine the potential for CBM production on federal lands. The private- and state-owned gas will be developed regardless of the outcome of this decision, but under the Proposed Action the project would include drilling CBM wells on both private, state, and federal oil and gas properties.

American proposes to drill areas within the Wyodak coal that are believed to trap free methane. This strategy reduces the need to depressure the coal seam which, in turn, minimizes the impacts to groundwater levels in the coal seam as well as potential environmental impacts associated with surface discharge of groundwater. By expanding this project onto lands with federally owned gas, American will have greater flexibility to locate and site wells in these structures. Thus, the efficiency of the operation is improved as is the efficiency of minimizing environmental impacts.

LOCATION OF THE PROPOSED ACTION

The proposed CBM project would be located in central Campbell County, Wyoming, in the eastern portion of the Powder River Basin south of American's successful CBM project. The wells would be located within a project boundary approximately 17 to 35 miles south of Gillette, Wyoming, in an area American has named the Lighthouse Field. Out of the 200 proposed CBM wells, approximately 100 would be drilled on federal minerals; the remaining would be located on private or state minerals. The project boundary is delineated by lease ownership, and there is no legal requirement for American to confine drilling to this area other than their federal oil and gas leases. The majority of private- and state-owned gas would be developed regardless of the outcome of this EA, but under the Proposed Action the project would include production from both private and federal oil and gas properties (map 1). It is significant to note that although approximately 1% of the project area is federal surface (map 2); federal oil and gas ownership constitutes about 45% of the potential project area. All federal mineral ownership, which includes coal, oil and gas, clinker, uranium, and sand and gravel, makes up about 91% of the potential project area.

AUTHORIZING ACTIONS

The BLM's Buffalo Resource Area administers oil and gas leases on federal minerals for this project. Leasing is subject to the limitations imposed by the *Buffalo Resource Management Plan/Record of Decision* (BLM 1985), by current policy, and by local, state, and federal laws. Before any surface disturbance can occur, American must have an APD approved by the BLM area manager for on-lease drilling and a right-of-way for off-lease disturbance on federal surface. BLM may require a coal exploration license as regulated under the Mineral Leasing Act of 1920, as amended, for drilling into a coal bed.

The WOGCC also requires an approved APD for wells drilled in the state, including federal wells. The state of Wyoming considers coal bed methane produced in conjunction with water to be a beneficial use and therefore requires an approved water well permit from the Wyoming State Engineer's office. Furthermore, the state of Wyoming's Department of Environmental Quality (DEQ) is responsible for granting a NPDES permit for discharge of any associated produced waters from any coal bed methane wells.

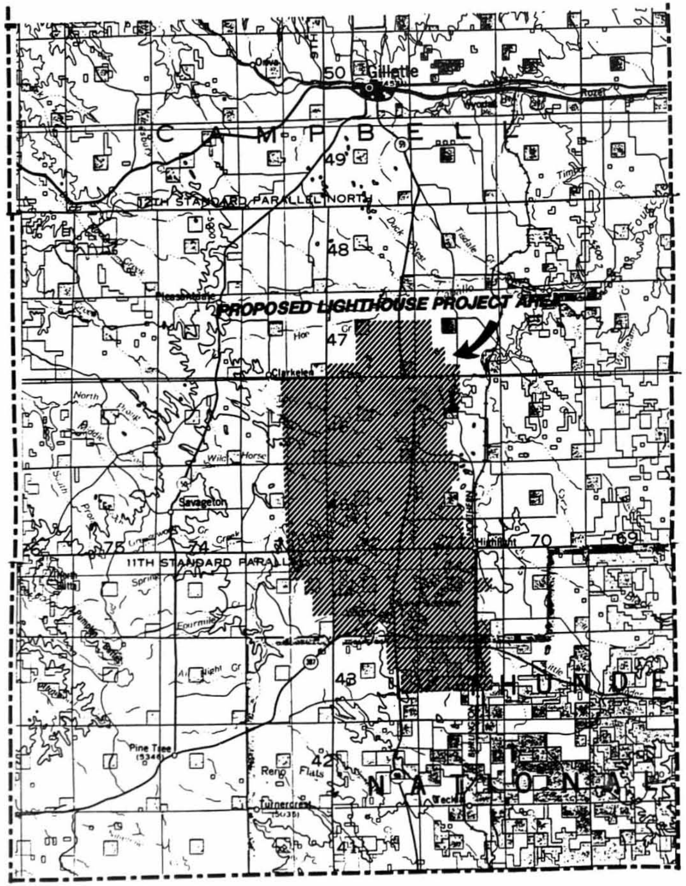
Given that this project will require associated construction of at least four gas compressor plants, noise and particulate emission permits will have to be secured by

The Proposed Project and Mineral Ownership

Scale: 1"=500,000'

Black Areas Represent Non Federal Minerals.
Shaded and Unshaded Areas Represent Federal Mineral Ownership to Varying Degree.

MAP 1



The Proposed Project and Land Ownership

Scale: 1"=500,000'

Unshaded Areas Represent Private Lands.
Shaded Areas Represent Federal and State Lands.

MAP 2

Western Gas Company (American Oil and Gas Incorporated's produced gas buyer for the proposed project) from the DEQ. No permits are presently required for the proposed project from Campbell County, the city of Gillette, or the city of Wright.

Finally, prior to area manager approval of the APD, American must secure necessary legal access to and across any privately owned lands.

As part of the APD approval process, BLM reviews the included surface use and drilling plan submitted by American. After the BLM receives the APD and prior to approval, an on-site inspection is made of the proposed drilling locations, access roads, and other potentially disturbed areas. BLM personnel, American's representatives, and the surface owner(s) usually attend the inspection to determine site-specific conditions for approving the APD. As part of the APD approval process, BLM requires standard protective measures in design and operation of the proposed project. Prior to construction, American would be required to follow Buffalo resource management plan decisions and comply with existing laws for threatened and endangered species; cultural, historical, and paleontological resources; and federally protected raptor nests. The proposed Lighthouse project is in conformance with the BLM's *Buffalo Resource Management Plan/Record of Decision* (BLM 1985). BLM would apply any appropriate stipulations to protect site-specific resources. A plan for monitoring and mitigating potential adverse impacts to groundwater is also proposed by American as part of their project design (chapter 2).

PUBLIC PARTICIPATION

The Council on Environmental Quality (CEQ) regulations require an "early and open process for determining the scope of issues to be addressed and for identifying significant issues related to a Proposed Action" (40 CFR 1501.7). Scoping was conducted through a direct mail process and public meetings. The mailing list included landowners, business groups, environmental groups, and any other interested members of the public.

Public scoping meetings were held on August 23, 1994 at the Campbell County Library, on August 25, 1994 at the Holiday Inn in Gillette, and on September 1, 1994 at the Holiday Inn in Gillette. All substantive comments BLM received during these meetings have been used to direct the scope and analysis of this EA. Additional public scoping comments were accepted through November 30, 1994. Two written comments were received during the comment period.

CHAPTER 2
ALTERNATIVES, INCLUDING THE PROPOSED ACTION

INTRODUCTION

A total of five alternatives were considered in this EA. The first, the Proposed Action, considered that a total of 200 wells (100 private and 100 federal) would be approved and drilled over approximately a five-year period. The other four alternatives were: 1) to reduce the number of wells approved; 2) to change the method of disposal of water on the land surface; 3) to consider underground injection of the produced water; and, 4) to reject all applications for federal wells (No Action).

ALTERNATIVE 1: THE PROPOSED ACTION

The proposed action consists of drilling, completing, and operating approximately 200 CBM wells in the eastern Powder River Basin of central Campbell County, Wyoming. Of these wells, a maximum of 100 would be located on lands where the oil and gas minerals are owned by the federal government (45% of the project area). These wells would be drilled in a staggered, sequential fashion over a five-year period. Each well's APD would be reviewed and approved on a case-by-case basis. This would allow conditions of approval to be developed for the CBM wells on the basis of monitoring.

The CBM wells would be located between 17 and 35 miles south of Gillette, Wyoming, in an area named the Lighthouse CBM project. As stated under the "Location of the Proposed Action" in chapter 1, the project boundary is delineated by lease ownership, and there is no legal requirement for American to confine drilling to this area other than on federal oil and gas leases. Even without BLM approval, the majority of private- and state-owned gas would be developed, but under the Proposed Action the project would include production from private, state, and federal oil and gas properties.

The project area is approximately 250 square miles (or 160,000 acres); average maximum well density would be 0.8 well per square mile. Because the wells tend to occur in groups, depending on the structure of the coal seam, and are drilled on a 40-acre spacing, large portions of the project area would never see any activity. Drilling would be by small truck-mounted water well rigs operated by no more than two to three people at a time. No more than one rig would be operating in the project area at any one time. This includes logging and cementing rigs as well. These operations should not disturb more than a 100- by 100-foot area for a drill pad. A temporary mud pit of no more than 8 feet deep, 10 feet wide, and 20 feet long should be required for each drilling and completion operation. Each producing well would be drilled to between a 350- to 1,200-foot depth and would have casing cemented to the top of

the coal seam. Access to the wells would be by two-track road. Some roads could be upgraded at a later date.

The BLM has a general policy that requires access roads to oil and gas wells on federal lands to be crowned, ditched, and in most cases, graveled or otherwise surfaced. For the Lighthouse project, an exception may be made to this policy in consideration of the following factors. As described above, the wells would be drilled using a water well rig. After wells are completed and equipment is installed, travel to the wells would be generally limited to one visit per day in a light truck or utility vehicle to check on operations, read meters, and provide light service. Such trips could be rescheduled or postponed during infrequent periods of wet weather when vehicular traffic could cause rutting. Troublesome areas, such as crossings of minor streams, could be upgraded as the need arises. Due to the flat terrain in this area very little earthwork would be required in access road construction. Additional disturbance would be required to provide the crowning and ditching normally required by BLM's general policy for oil and gas well access roads. Most of the access roads are on privately owned lands, and the owners have expressed to American a desire to have surface disturbance, including road construction, minimized. Based on the foregoing, the Proposed Action does not include conventional crowned, ditched, and surface roads such as BLM requires in conventional oil and gas operations.

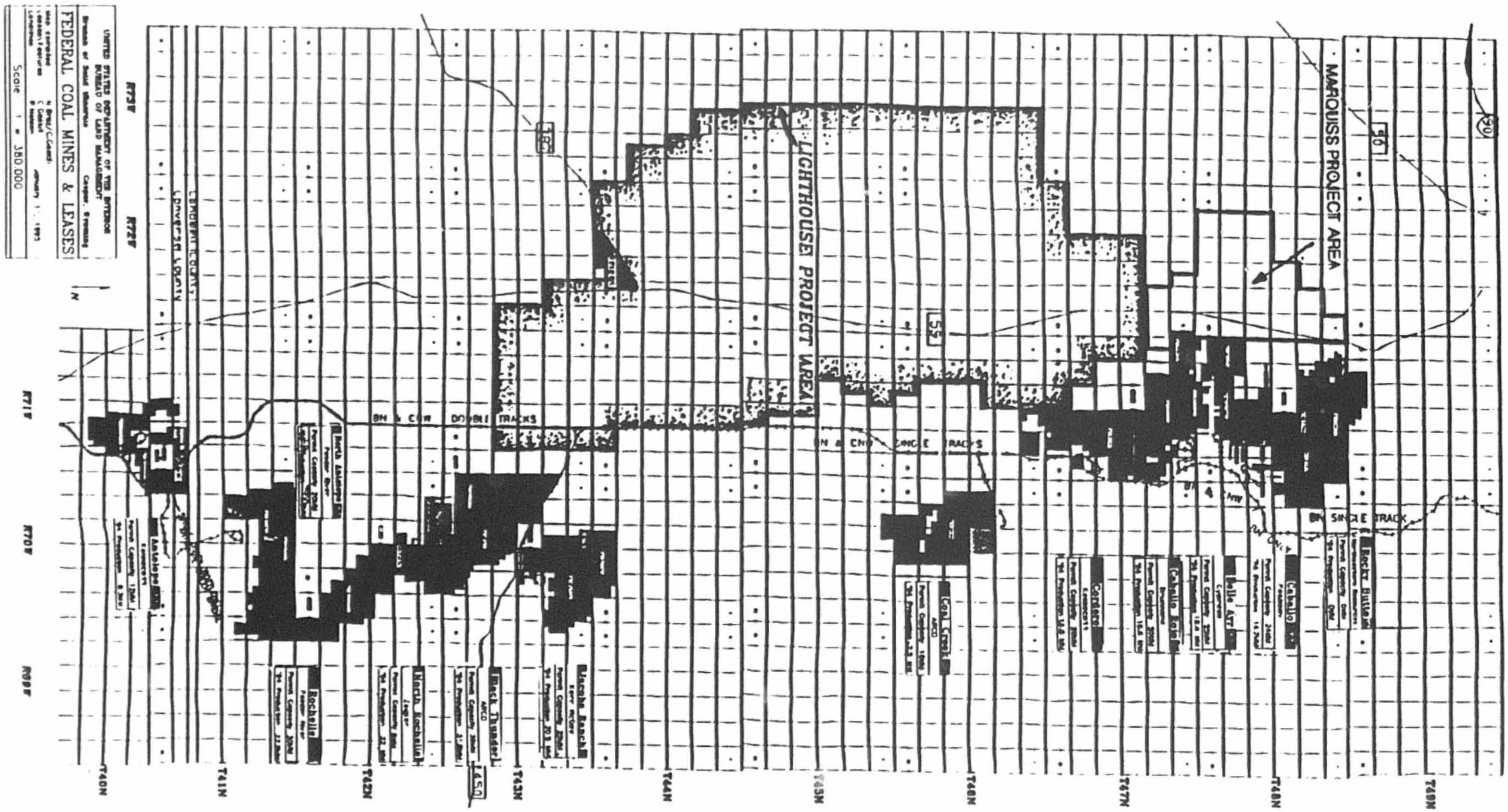
The project would be phased in through time and geography. The overall drilling activity would proceed north to south across the project area and correspond to an estimated 5-year timeframe. A certain number of wells would be drilled and hooked up to pipelines each year within limited portions of the project area. American projects that between 25 and 50 wells could be drilled in any given year, of which about one-half are likely to be federal wells. American estimates that no more than 100 wells would be on the federal minerals. The more likely scenario is for American to drill 30 wells per year and finalize the project at 150 wells, of which 75 might be on federal minerals. This compares to a total of 64 wells completed in the Marquiss Project drilled over a 3-year period. The low-range scenario could result from various economic factors that would cause American to limit its activity, resulting in as few as 100 total wells, or 50 federal wells. The estimated productive life of the project is 10 to 20 years.

The Proposed Action would consist of four basic components: a) the CBM wells; b) the gas gathering and delivery system; c) the water disposal system; and, d) the hydrologic monitoring system. These components are described below.

CBM Wells

At the Lighthouse Field, CBM would be produced by drilling wells at selected locations in the Wyodak coal seam. This is the same seam that is being mined by 19 active surface coal mines in the Gillette coal field (map 3). Eight of these 19 mines are in

MAP 3



The Proposed Project Area and Adjacent Coal Mines and Leases

the immediate vicinity of the proposed action. These coal mines are located along the outcrop of the coal seam where the relatively thin overburden is conducive to surface mining.

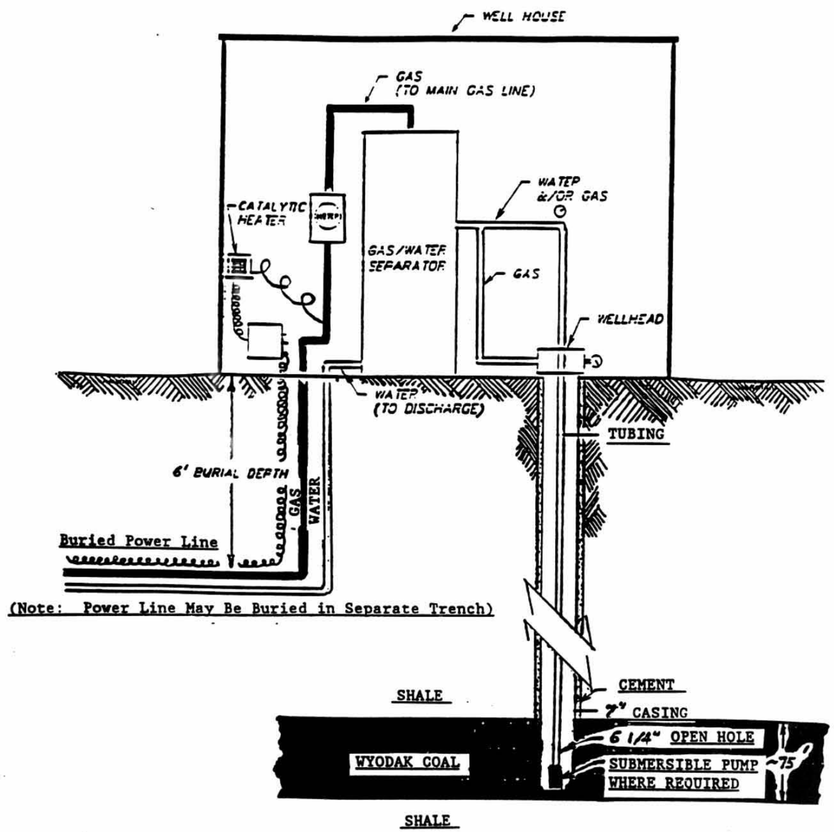
All proposed wells are expected to flow both water and methane gas at the surface for a variable period of time. In other wells it would be necessary to pump water until the associated pressure decline in the coal bed is sufficient for methane to begin to flow into the well bore. Methane would be produced until reserves decline to subeconomic levels of methane production. Production from each CBM well is estimated to range from 50 to 500 thousand cubic feet (mcf) per day when the wells achieve optimal production.

The CBM wells are located on anticlinal (dome-shaped) structures of the coal where free methane may exist in traps or where minimal pressure reductions are required to begin methane production. These structures in the coal are target CBM production sites because their shape provides natural traps for gas in the coal seam, and the structures are often associated with enhanced fracture permeability in the coal seam. This allows economic recovery of methane with fewer wells and reduced water production as compared to typical CBM projects.

The CBM well bores would be uncased in the coal, and the wells would be cased and cemented from the land surface to the top of the coal seam to prevent hydraulic communication (connection) through the well bore between the coal seam and the overlying Wasatch Formation. Figure 1 is a typical CBM well completion diagram. An unknown number of wells would require the installation of submersible pumps which would be used to produce water as necessary to lower the pressure in the coal seam, thus permitting methane to displace the water in the fractures (or cleats) in the coal seam and become available for recovery in the well. Other CBM wells would encounter free gas under pressure allowing the gas to be produced by flowing to the surface in tubing installed in the well bore. Wells encountering free gas would not require pump installation. Production of water is expected not to exceed 11 gallons per minute per well.

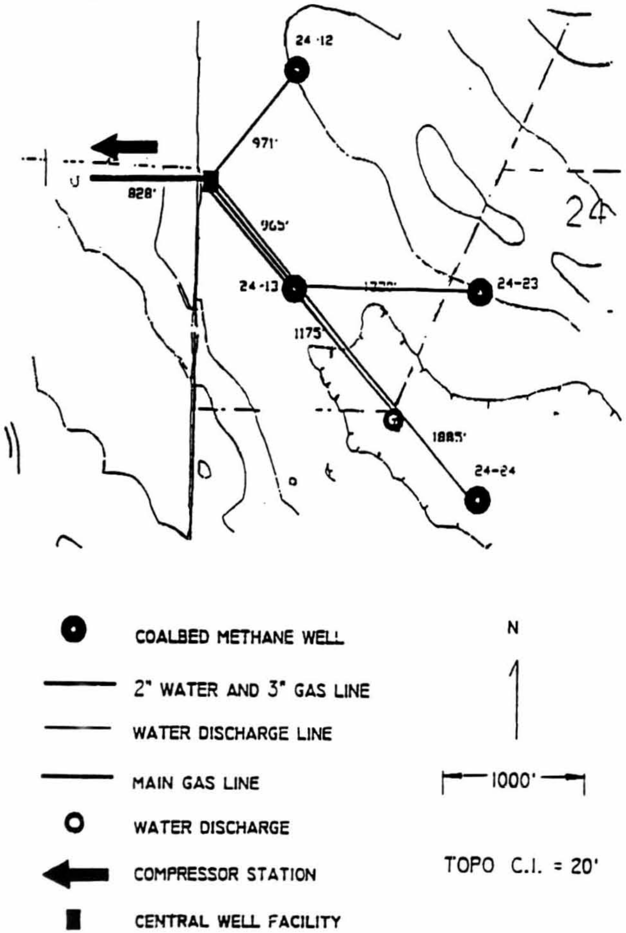
The proposed development scenario calls for a yearly progression of drilling and production from roughly north to south across the project area. The wells would be distributed in a grouping or "pod" of approximately 50 wells each. Within each "pod" American proposes that the most effective production facility design would tie six or more wells in a cluster to a central gathering facility. From this "facility," the gas would be transferred by buried pipeline to a central processing plant and thence to the pipeline (figure 2). It is estimated that four processing facilities would need to be constructed to serve the estimated production and sales.

American proposes to minimize the size of all surface facilities used in the project. Gas and water from two to ten wells would be handled in one well building to mini-



TYPICAL AMERICAN OIL & GAS CBM WELL WITH SUBMERSIBLE PUMP

Figure 1



Typical Plan View of Multiwell Production Facility in the Lighthouse Project Area.

Gas and water from each well are piped via 2" and 3" poly pipe to a central well facility where metering occurs. Water is then piped to a discharge point and gas is piped to the compressor station.

(Source: American Oil & Gas. 1995)

Figure 2

mize disturbance. Incoming gas would be metered and then would flow into the gas line toward the compressor. Incoming water would be separated from its gas; the water would be directed toward a discharge point; and, the gas metered and directed toward the gas line.

Each CBM well, upon completion and evaluation, would be tested for use as a methane production well. If found suitable, each may be equipped with the following:

- ✓ A submersible pump (about 1 to 2 horsepower) to depressure the coal seam by evacuating sufficient water to initiate gas flow.
- ✓ A water-gas separator.
- ✓ Piping and fittings necessary to connect the wellhead with discharge lines to convey water to discharge facilitates and gas to a compressor station.

American will seek to bury power lines and water and gas lines used to connect production wells with facilities in trenches wherever possible. These gas and water lines would be laid in a trench approximately six feet deep. Electric lines may be laid in the same trench at a two-foot depth. Power to each well would be provided by Tri-County REA.

Gas Gathering and Delivery System

The gas gathering and delivery system would consist of black polyethylene pipe 1½ to 8 inches in diameter extending from each well to a compressor station which would compress the gas for delivery to a high-pressure gas transmission line (figure 2). The gas line from the CBM wells to the compressor station would be installed with the use of a ditch-witch or similar vehicle.

The pipeline would be assembled outside of the trench. After the pipeline is assembled and laid in the trench, the dirt would be bladed back into the trench and mounded to allow for settlement. The total width of disturbance along the trench is less than 10 feet. The total area disturbed by the pipeline construction is estimated to be about 50 acres.

The proposed project would require construction of gas compressor facilities. These facilities would be consrtucted and operated by Western Gas Incorporated who is also the presently contracted buyer for the methane gas to be produced by American. Assuming that one compressor plant would be required for each 50-well group, at least four compressor facilities would be required for the projected 200 wells. Each of the compressor plants would be rated at between 800 and 1,200 horsepower and would be tied into large diameter pipelines that presently exist in the project area. These compressor stations would occupy approximately six acres of surface.

Water Disposal System

The water which must be pumped from the CBM wells to initiate gas flow and the water from the water-gas separator would be disposed of by discharging to area drainages. This disposal method has been practiced by American at the Rawhide Butte CBM project northwest of Gillette and the Marquiss project immediately north of this project with no problems. It has also been well received by the landowners. The discharged water helps maintain water levels in stock ponds and supports vegetation production and wildlife habitat along the receiving streams.

Based on experience from the Marquiss project, it is estimated that CBM wells which produce water or which require pumping to initiate gas flow would produce water initially at an average of 9 to 12 gallons per minute (gpm) and would decline to about 3 gpm per well. To the extent possible, the water discharge lines from each well would be placed into the same trench as the gas gathering lines to minimize construction costs and surface disturbance. The water discharge lines, like the low-pressure gas lines, would be poly pipe with a diameter of 2 inches, depending on how many wells can be networked into the same line. The discharge lines would be networked such that several wells are linked together to one common discharge point. As has been done at the Marquiss and Rawhide Butte projects, discharge points would be selected after consultation with the landowners to find locations which would provide maximum benefits.

The receiving drainages would be tributaries to the Belle Fourche and Cheyenne rivers.

The discharge of water would most likely be distributed to approximately 40 points (or 5 wells per discharge point). Assuming an average maximum of 10 gpm per well, the discharge at any point should not exceed 50 gpm.

Hydrologic Monitoring System

An integral part of the Proposed Action is a hydrologic monitoring system required to detect impacts to other water users and to provide data for control and operation of the methane production project. The monitoring program will include groundwater and surface water monitoring, and the monitoring required under the terms of the NPDES discharge permit issued by the state of Wyoming. The monitoring program was designed to provide early warning if nearby water wells are susceptible to unacceptable loss in hydraulic head as a result of CBM development activities.

Whether production of methane occurs by encountering free gas trapped in the coal seam or by pumping water to reduce pressure and induce gas flow, it is possible that nearby water wells completed in the coal could experience a decline in head (for example, an increase in the depth to water in the well bore). If the decline in head is a

significant part of the total available head at a particular water well, then that water well could experience a reduction in yield.

Monitoring would be initiated on the Lighthouse project to validate predicted impacts and to identify the need to mitigate impacts. General monitoring activities are outlined below.

<u>Baseline Inventory.</u> This inventory would include measurements of static water levels and methane concentrations at wells (both water wells and CBM wells) throughout the project area including a 2-mile buffer area around the project.

<u>Periodic Coal Aquifer Monitoring.</u> This monitoring consists of periodic (monthly) measurements of water levels and gas concentrations at selected wells. The data would be used to ensure that predicted impacts to the coal aquifer are not exceeded and to identify a potential need for mitigation.

<u>Continuous Coal Aquifer Monitoring.</u> This monitoring consists of continuous measurements of water levels and gas pressure in wells completed in the coal aquifer (the methane target zone). The data collected at these wells would be used to identify natural fluctuations (for example, daily and seasonal) and to isolate the effects of the coal bed methane development from other activities occurring in the coal bed. The information collected would also be used to validate periodic measurements as described above.

<u>Paired Well Monitoring.</u> These monitoring sites consist of paired wells--one completed in the coal aquifer and a second completed in the next adjacent sand zone (above or below the coal). This monitoring would determine if vertical leakage is occurring between aquifers.

<u>Surface Water Monitoring.</u> This monitoring would provide information to prevent undue degradation to surface water resources (water quality as well as surface drainages) would not occur. Monitoring would address discharge volumes, water quality, changes in stream flow off the project area, and qualitative monitoring of channel morphology.

<u>Groundwater Quality Monitoring.</u> Periodic water quality samples would be taken at selected monitoring wells as well as from the discharge points to ensure that the quality of water encountered is similar to that used to describe the predicted impacts of the project.

<u>Specific Monitoring Activities.</u>

Groundwater. The following is the monitoring that would be done by American:

✓ Baseline water levels and gas concentration: all water wells within the project area plus a 2-mile buffer zone outside of project area.

✓ Monthly monitoring of selected wells within and around the project area.

✓ Periodic monitoring of static water levels in CBM production wells as required by the Wyoming State Engineers Office (SEO). It is expected that the SEO would require the operator to submit monthly reports containing the following information for each CBM well: (a) well name, permit number and location; (b) reporting dates, name of individual responsible for report, and method of measurement; (c) total volumes of water and gas produced during the reporting period and cumulatively since reporting began; (d) bottom of hole pressure build-up during a minimum 8-hour shut-in period once every 45 days; and, (e) remarks or comments regarding data acquisition. These reporting requirements were established by the SEO for coal bed methane projects.

✓ Cumulative monitoring of water production at each CBM production well.

The following is the monitoring that would be done by the BLM to provide independent verification of hydrologic activities:

✓ Continuous monitoring of groundwater levels and gas pressure of selected wells completed in the coal and periodic (one to two months) measurement of methane concentration at these wells. In addition, four of these monitoring sites would include a second well completed in the next shallower sand above the coal near the coal well (less than 300 feet). The other well pair includes a coal completion well and a well completed in the next sand below the coal. The approximate locations for these sites are listed in table 1.

TABLE 1
PROPOSED SCHEDULE FOR INSTALLING DEDICATED MONITORING WELLS

APPROXIMATE PROPOSED WELL LOCATION	APPROXIMATE DEPTH (feet below land surface)	TARGET ZONE OF COMPLETION (feet)	PROPOSED INSTALLATION DATE AND STATE OF WYOMING PERMIT NUMBER	COMMENTS
T. 48 N., R. 72 W. SWSE, section 22	510	coal 430 - 510	completed 2-6-93 (U.W. 90658)	Coal well of a pair of wells completed for the Marquiss project.
T. 48 N., R. 72 W. SWSW, section 22	410	sand 340 - 410	completed 2-6-93 (U.W. 90659)	Sand well of well pair.
T. 47 N., R. 72 W. SWNW, section 2	407	coal 327 - 407	completed 4-1-93 (U.W. 90656)	Coal well of a pair of wells completed for the Marquiss project.
T. 47 N., R. 72 W. SWNW, section 2	310	sand 260 - 310	completed 4-1-93 (U.W. 90657)	Sand well of well pair.
T. 47 N., R. 72 W. SWNW, section 36	500	coal	existing	Existing (Amoco well).
T. 47 N., R. 71 W. section 29	460	coal	existing	Existing (Cordero well).

TABLE 1
PROPOSED SCHEDULE FOR INSTALLING DEDICATED MONITORING WELLS
(continued)

APPROXIMATE PROPOSED WELL LOCATION	APPROXIMATE DEPTH (feet below land surface)	TARGET ZONE OF COMPLETION (feet)	PROPOSED INSTALLATION DATE AND STATE OF WYOMING PERMIT NUMBER	COMMENTS
T. 46 N., R. 72 W. section 14	800 (approx.)	coal	year two	Coal well of well pair.
T. 46 N., R. 72 W. section 36	500 (approx.)	coal	existing (U.W. 97263)	Use this existing American well for monitoring for first year or until needed for production.
T. 45 N., R. 71 W. section 4	500 (approx.)	coal	year two	
T. 45 N., R. 70 W. section 30	300 (approx.)	coal	year two	
T. 45 N., R. 72 W. section 10		coal	year one	Use this American well for two years.
T. 45 N., R. 72 W. section 15	800 (approx.)	coal	year two	Coal well of a pair (coal/sand) of wells. This well will replace section 10 well when American takes over.
T. 45 N., R. 72 W. section 15	700 (approx.)	sand above coal	year two	Shallower sand well of a well pair (coal/sand).
T. 45 N., R. 73 W. section 2	1,000 (approx.)	coal	year two	
T. 44 N., R. 72 W. section 7	800 (approx.)	coal	year three	
T. 44 N., R. 73 W. section 14	900 (approx.)	coal	year three	Coal well of a pair of wells (coal/sand).
T. 44 N., R. 73 W. section 14	800 (approx.)	sand	year three	Sand well completed in the next sand aquifer above the coal.
T. 44 N., R. 71 W. section 30	500 (approx.)	coal	year three	Coal well of a pair (coal/sand).
T. 44 N., R. 71 W. section 30	600 (approx.)	sand	year three	Sand well of a pair (coal/sand).

✓ Periodic spot checking of measurements made by American on their monitoring wells.

✓ Periodic (one to two times per year) monitoring of additional water wells further from the project area that American is not monitoring.

✓ Water quality samples would be taken from the monitoring wells on an annual basis and analyzed for the following constituents.

PARAMETER	UNIT
pH	Std Units
Electrical conductivity	umhos/cm
Bicarbonate	mg/l
Chloride	mg/l
Sulfate	mg/l
Carbonate	mg/l
Fluoride	mg/l
Calcium	mg/l
Potassium	mg/l
Magnesium	mg/l
Sodium	mg/l
Aluminum	µg/L
Arsenic	µg/L
Barium	µg/L
Boron	µg/L
Cadmium	µg/L
Chromium	µg/L
Copper	µg/L
Iron	µg/L
Lead	µg/L
Mercury	µg/L
Selenium	µg/L
Silica	µg/L
Silver	µg/L
Zinc	µg/L

✓ At least one multi-well aquifer test would be run to validate the assumptions of aquifer anisotropy and aquifer characteristics presented in this EA.

Surface Water. The following is the monitoring that would be done by American:

✓ Monitoring of volume and quality of produced water being discharged to the surface as required by the Wyoming, Department of Environmental Quality (WDEQ) under the National Pollution Discharge Elimination System (NPDES).

The following is the monitoring that would be done by the BLM:

✓ Operation of a surface water gauging station on the Belle Fourche River below the area to be affected by surface discharge of produced water from the Lighthouse project and above the areas influenced by the coal mines.

At this station stream flow, water temperature, and electrical conductivity of the water would be continuously recorded. In addition, periodic manually collected samples would be analyzed for the constituents listed above with the addition of total suspended sediments (TSS).

✓ Periodic check sampling of water quality would be done at the Lighthouse discharge points and analyzed as above.

✓ Channels receiving the produced water would be monitored for signs of accelerated erosion and degradation.

Cost Share on the Wells to be Monitored by the BLM. Where suitable wells do not exist for monitoring, American would drill and complete wells (including logging and cementing) where necessary. The BLM would provide materials (casing and, where needed, gravel pack and bentonite) and all instrumentation and necessary support facilities (shelter and fence). The data obtained from these wells will also be used for the basinwide hydrologic study being done by the BLM and cooperating agencies.

Implementation of Monitoring. This project is to be brought on line in a phased manner, starting in the north and working south. Monitoring would be phased in as drilling proceeds (table 1).

The well locations and scheduling in table 1 are approximate. If adequate existing wells are available they may be substituted for some of the wells above (or possibly added to the network). The monitoring well schedule and final location would ultimately be a function of the final development scenario and development schedule.

ALTERNATIVES CONSIDERED BUT NOT ANALYZED IN DETAIL

Reduce the Number of Federal Wells Approved

This alternative considered the drilling of fewer than 100 wells in a sequential manner. It was not analyzed in detail because there is enough flexibility in the implementation of the Proposed Action to approve fewer than 100 wells. The decision to approve each well is based on the site-specific analysis completed for each APD. Impacts of this alternative would be less than the Proposed Action and therefore have not been analyzed.

Change the Method of Surface Water Disposal

This alternative was not analyzed in detailed because water discharges at the Rawhide Butte project (which has been producing coal bed methane for five years) north of Gillette and the Marquiss project adjacent to this one have not caused any major problems. Also, discharges are regulated by the state of Wyoming under NPDES, and the produced water from this project would meet those standards.

Inject Produced Water Underground

Underground injection to dispose of the produced water was considered. The produced water should be of relatively good quality. Total dissolved solid (TDS) levels are expected to be from 500 to 1,000 milligrams per liter (mg/l), well within Wyoming standards for livestock water. The produced water can only be disposed of in aquifers exempt from the definition of fresh and potable water (WOGCC 1989). Injection of this water into an exempt formation would make water now suitable for irrigation and livestock unusable for any future use and would only mitigate potential surface water impacts and none of the potential groundwater impacts. Reinjection into the coal seam might be feasible but would also defeat the purpose of removing water from the coal seam to produce methane. Also, reinjection would require a system of wells and pipelines that would increase the total surface disturbances. Finally, because the produced water is expected to be suitable for livestock and wildlife and possibly irrigation, it should be put to beneficial uses.

No Action: Reject All Applications for Federal Wells

Section 1502.14(d) of NEPA requires that alternatives analysis in the EA "include the alternative of no action." The Department of the Interior's authority to implement a "No Action" alternative is limited. An explanation of this limitation and the discretion the Department has in this regard is as follows.

An oil and gas lease grants the lessee the "right and privilege to drill for, mine, extract, remove and dispose of all oil and gas deposits" in the leased lands, subject to the terms and conditions incorporated in the lease (Form 3110-2). Because the Secretary of the Interior has the authority and responsibility to protect the environment within federal oil and gas leases, restrictions are imposed on the lease terms.

Leases within the Lighthouse analysis area contain various stipulations concerning surface disturbance, surface occupancy and limited surface use. In addition, the lease stipulations provide that the Department of the Interior may impose "such reasonable conditions, not inconsistent wit the purposes for which (the) lease is issued, as the (BLM) may require to protect the surface of these leased lands and environment." None of the stipulations would empower the Secretary of the Interior to deny all drilling activity because of environmental concerns.

Provisions in leases that expressly provide Secretarial authority to deny or restrict APD development in whole or in part would depend on an opinion provided by the U.S. Fish and Wildlife Service (FWS) regarding impacts to endangered or threatened species or habitats of plants or animals that are listed or proposed for listing (for example, bald eagle). If the FWS concludes that the proposed action and alternatives would likely jeopardize the continued existence of any endangered or threatened plant or animal species, then the APD(s) and Lighthouse development may be denied in whole or in part.

CHAPTER 3
THE AFFECTED ENVIRONMENT

INTRODUCTION

These elements or resources are either not affected or not present in the analysis area and will not be discussed further: areas of critical environmental concern, prime or unique farmlands, floodplains, Native American religious concerns, hazardous wastes, wild and scenic rivers, wilderness or wilderness study areas, and paleontological resources.

The description of the affected environment focuses primarily on hydrologic and hydrogeologic conditions at the Lighthouse Field because it is believed these aspects of the environment are the most likely to be impacted by the proposal. Other aspects of the environment have been discussed in the Buffalo RMP (BLM 1985), the BRA Oil and Gas Environmental Assessment (BLM 1980), the West Rocky Butte Coal Lease Application Environmental Impact Statement (BLM 1992a), the Belle Ayr Coal Mine Permit Application (AMAX 1988), the Caballo Coal Mine Permit Application (Carter 1985), and the Caballo Rojo Coal Mine Permit Application (Mobil 1985).

The Lighthouse Field is located in the eastern portion of the Powder River Basin south of American's previous CBM drilling project (Marquiss). This topographic and structural basin is bounded by the Black Hills to the east, the Big Horn Mountains to the west, the Hartville Uplift to the south, and the Missouri River Breaks to the north. The local landscape is characterized by rolling hills covered with grass and sage. To the east the topography changes abruptly to rough broken clinker hills. Numerous clinker- and sandstone-capped buttes extend to the west. The major drainages in the immediate area are the Belle Fourche and Cheyenne rivers, which flow generally west to east through the project area, and its tributaries.

GEOLOGY AND MINERAL RESOURCES

The proposed Lighthouse project area is located within the Powder River structural basin. The topography is that of rolling divides that have low local topographic relief.

The Powder River Basin in general and Campbell County in particular represent one of the major mineral development areas in North America (Fox, Dolton, and Clayton 1991). The proposed project located in the south-central portion of Campbell County shares in the unique geologic character of the Powder River Basin that has yielded significant mineral resources and reserves (Flores and Cross 1991). This has been particularly true for oil, gas, and coal.

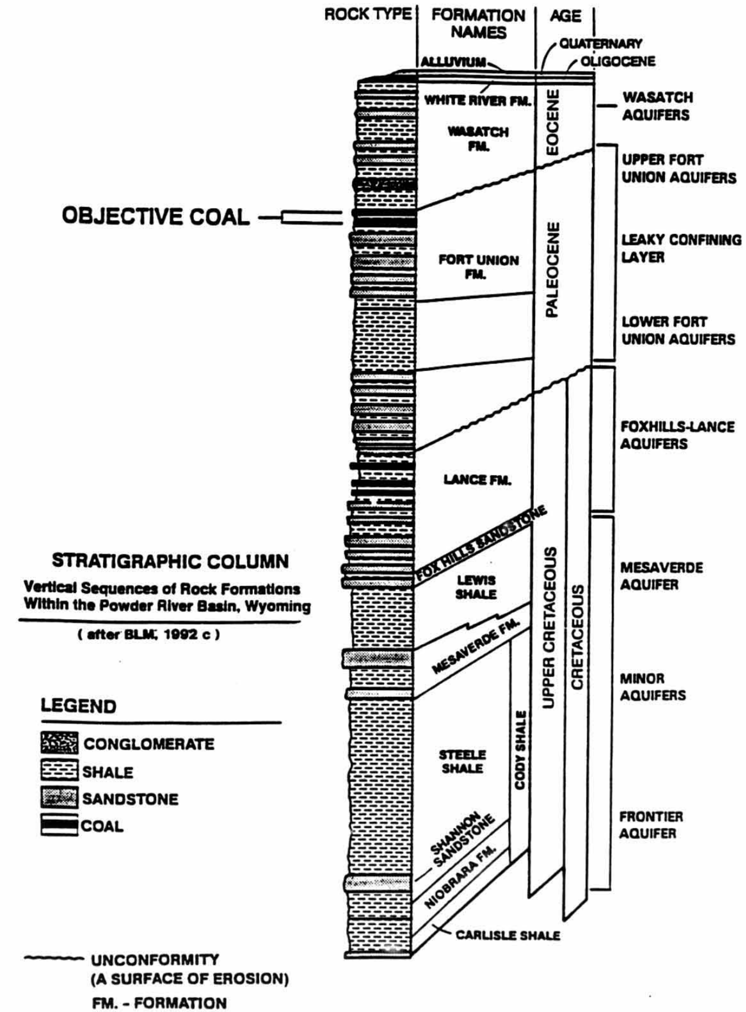
The proposed project is located on the eastern limb of the Powder River Basin which was formed during the Laramide Orogeny (mountain building) during the Late Cretaceous/Early Tertiary periods from 58 to 65 million years ago. Basin sediments were derived from the Big Horn Mountains, the Casper Arch, the Laramie Range, the Hartville Uplift, and the Black Hills. The three primary geologic units affected by the project include Quaternary alluvium and Tertiary Wasatch formations and the older Tertiary Fort Union Formation (figure 3).

The Quaternary alluvium deposits found in stream beds and gullies were caused by erosional reworking of older sedimentary deposits in the area. These deposits include mainly silt- to gravel-sized particles from sandstones, siltstones, claystones, clinker, and clinker from the surrounding the deposits. These deposits are found at lower elevations along drainages passing through the area.

The older Wasatch Formation is the only other formation exposed at the surface in the project area. Scattered sedimentary deposits exposed throughout the project area include interbedded sandstones, siltstones, coal, clinker (coal ash and baked shale), and shales.

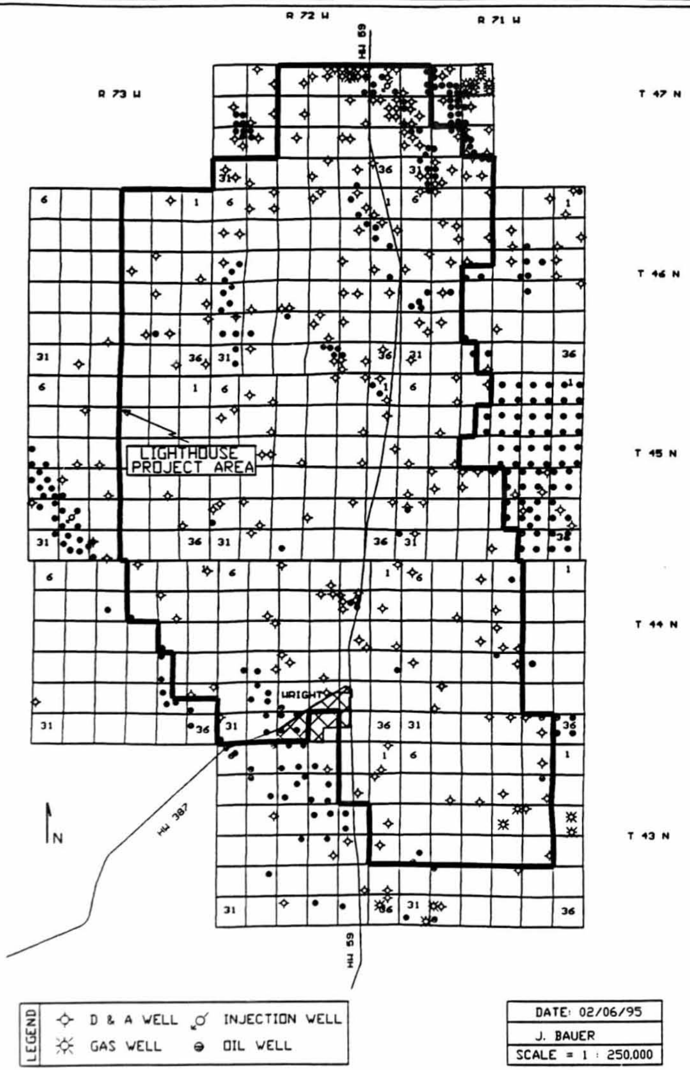
The Fort Union Formation is composed of interbedded sandstones, siltstones, shales, claystones, coal, and clinker. The Tongue River member of the Fort Union Formation, consisting of about 600 feet of sedimentary deposits, contains the Wyodak-Anderson coal seam (the primary zone of interest). The methane gas contained in this coal seam exists as free gas, adsorbed on interior pore surfaces and micropores of the coal matrix, and dissolved in the water. Reducing the hydrostatic pressure on the coal seam by pumping off the water enhances the release and production of the methane gas previously trapped in the coal matrix as well as gas dissolved in the water. The Wyodak-Anderson coal seam is between 60 and 70 feet thick with a maximum thickness of about 100 feet and ranges from between 200 and 1,000 feet below the ground surface, increasing in depth from east to west. This coal seam is mined extensively in open pit mines where it outcrops east of the project area (map 3). Several less significant coal seams lie above and below the Wyodak-Anderson coal seam.

Conventional oil and gas exploration and production has occurred in the project area, with the majority of the drilling penetrating the Wyodak-Anderson coal seam. Spread among all or part of 19 existing oil and gas fields in the proposed project area are 90 currently producing oil wells and 15 gas wells (map 4). Approximately 312 oil and gas wells have been drilled in the proposed project area. The target oil and gas formations underlying the Wyodak-Anderson coal seam include the Upper Cretaceous Parkman Sandstone, Sussex Sandstone, Lower Cretaceous Mowry Shale, Muddy Sandstone, Skull Creek, Dakota, Lakota, and Permian/Pennsylvanian Minnelusa.



Lighthouse Project Area

Figure 3 Subsurface Geology and Hydrogeology



MAP 4
Existing Oil and Gas Wells and Project Area

The nature of occurrence and significance of the CBM resource has been well described and discussed in other places (Henderson 1991; Law, et al. 1991; WGA 1989). The most significant fact about this resource in the proposed project area is that it constitutes an economically viable methane gas reserve. These reserves are located at shallow depths and can be produced at a relatively low cost.

WATER RESOURCES

Groundwater

Groundwater in and near the project area is used for a variety of purposes, including domestic, municipal, industrial, and agricultural uses. Domestic and livestock wells are usually low yield (1 to 25 gpm) intermittent producers. Water suitable for domestic and livestock uses can generally be found at less than 1,000 feet below the surface. Industrial water wells are used primarily for obtaining water for use in subsurface injection to promote secondary recovery of petroleum. At the coal mines these wells are used for drinking water and dust abatement.

There are nearly 2,800 SEO permitted water wells, of which approximately 1,450 are not monitor wells, in and around the project area (T. 44-48 N., R. 70-74 W.). Of these 1,450 wells, only 87 are probable coal or upper Fort Union completions not owned by American. The list is too lengthy to include in this document but is available at either the BLM Buffalo Resource Area Office or the BLM Casper District Office. The water well location data for all permitted water wells in the state of Wyoming is available from the SEO. Table 2 is a tabulation of these wells by primary use.

The project area is underlain by what can be divided into four major bedrock aquifer systems--the Paleozoic-aged Madison, the Lower Cretaceous Dakota, the Upper Cretaceous Lance/Fox Hills, and the Lower Tertiary Wasatch/Fort Union. The Wyodak coal is the top of the Fort Union sequence. Minor aquifers of local importance in the area include the Quaternary alluvial aquifers. These represent the majority of the significant water-bearing strata; however, there are a few wells completed in formations which are included in "aquitard" groups. These are generally lower yield and poorer quality except near the outcrop. In addition to the water supplies that can be developed from these aquifers, there are a few springs generally of the contact type, often at the base of the clinker. Since only the wells completed in the Fort Union and shallower formations have any possibility of impact due to this project, only those formations are discussed below. A generalized cross section of the Wasatch/Fort Union geology of this area is described in table 3.

TABLE 2
KINDS AND NUMBER OF WELLS IN THE PROJECT AREA
(T. 44-48 N., R. 70-74 W.)

PRIMARY USE	NUMBER	UPPER FORT UNION
Dewater	101	---
Domestic	82	9
Industrial	91	2
Irrigation	10	0
Miscellaneous	374	---
Monitor	1,339	---
Municipal	4	0
Reservoir	34	0
Stock	725	76
Unknown	29	0
TOTAL	2,789	87

The Wasatch/Fort Union aquifer group includes the Wasatch Formation and the Tongue River (which includes the Wyodak coal), Lebo, and Tullock members of the Fort Union Formation. The shallowest of the bedrock aquifer systems in the Powder River Basin, it ranges to over 3,000 feet thick (Feathers et al. 1981). The Wasatch and Fort Union aquifers are the most important local source of groundwater in the Powder River Basin (Feathers et al. 1981). They are developed extensively for shallow domestic and stock wells.

The Wasatch aquifer consists primarily of fine- to medium-grained lenticular sandstone beds and sand channels surrounded and interbedded with siltstone, shales, and coals. Thickness ranges from approximately 300 (east boundary of project) to over 1,000 feet on the west edge of the project boundary. Wells completed in Wasatch shales and siltstones generally do not yield enough water even for intermittent livestock use.

Wells completed in sandstone lenses or sand channels yield 10 to 50 gpm. Artesian conditions are common away from the outcrop and particularly in the deeper isolated sands. Recharge to the Wasatch Formation is through surface infiltration of precipitation and lateral movement of water from adjacent clinker and alluvium.

TABLE 3
GENERALIZED DESCRIPTION OF THE SHALLOW GEOLOGY WITHIN THE LIGHTHOUSE PROJECT AREA

FORMATION	DESCRIPTION	AQUIFER CHARACTERISTICS
Wasatch	Interbedded sandstones, siltstones, shales, and coal. The sandstones are generally discontinuous paleochannel deposits or lenticular in nature.	Discontinuous lenticular sands, fine- to medium-grained; generally supply adequate quantities for stock use.
Aquitard	Thick shale layer, 10 or more feet thick found on top of the Wyodak coal.	Aquiclude (impermeable layer).
Wasatch/Fort Union Contact		
Wyodak coal	Coal, 50 to 100 or more feet thick.	Continuous, fractured coal seam.
Aquitard	Shale layer commonly present at the base of the Wyodak.	Aquiclude (impermeable layer).
Upper Fort Union (Tongue River/ Lebo)	Interbedded sandstones, siltstones, shales, and coals.	Sands fine- to medium-grained; Lebo is a leaky confining layer between Upper and Lower Fort Union.
Lower Fort Union/Tullock	Interbedded sandstones, shales, and coal.	Sands somewhat coarser than Upper Fort Union; sand at base of Fort Union (Tullock) a good producer and regularly used industrially.

Natural discharge occurs at small seeps and springs along surface drainages and from evapotranspiration. Local flow systems are predominant with discharge occurring along creeks and tributaries near recharge areas. Regional groundwater movement (if present) is towards the north but is extremely slow due to the fine-grained and discontinuous nature of most of the Wasatch. Dissolved solids concentrations in the Wasatch range from 141 to 9,710 mg/l and have a median concentration of 825 mg/l (USGS 1984). Analysis from approximately 143 wells completed in the Wasatch in and near the project area range from 146 to 8,200 mg/l and have an average concentration of 1,415 mg/l (appendix).

The Wyodak coal is the top of the Fort Union sequence. Water in the Wyodak coal away from the outcrop is confined by shale at the base of the overlying Wasatch Formation and by a thick shale sequence underlying the coal (USGS 1988). The fact that the coal is a confined aquifer away from the outcrop is further documented by the USGS (1986a) and in various mine permit application packages (PAPs) on file with the WDEQ/Land Quality Division (LQD). Artesian conditions exist away from the outcrop.

The aquifer consists of the Wyodak and associated coals where the Wyodak splits and separates into multiple beds, interbedded sandstones, and clinker beds at the outcrop. Flow of water in the aquifer is affected in places where the coal bed splits and is interbedded with claystone, shale, and sandstone. Flow in the aquifer is also affected by differences in aquifer properties caused by the varying pattern and degree of fracturing in the coal. The permeability of the coal bed is a function of fracturing. Therefore, the coal is not isotropic (uniform) and the flow occurs in the fractures within the coal. Wells completed within the coal generally yield from 10 to 50 gpm (USGS 1975). Recharge occurs primarily along the clinker outcrop areas.

Recharge and discharge also occur locally outside of the project area where the coal outcrops under the floor of alluvium-filled valleys (USGS 1988). As more of the operating mines are reclaimed, reclaimed mine areas may become recharge areas to the adjacent, undisturbed Wyodak coal. Regional flow is to the north and away from the recharge areas as indicated by the potentiometric surface map prepared by Daddow (USGS 1986a). Local flow patterns may differ from regional flow. Water quality of the Fort Union Formation (including the Wyodak coal and the Tongue River/Lebo and Tullock members) is quite variable, with ranges of TDS concentrations from 200 to over 4,000 mg/l. Average concentration for 72 samples in the project area from the Fort Union Formation is 1,349 mg/l (USGS 1984). The best quality water is generally obtained from the clinker areas, and the coal generally contains 1,000 to 2,000 mg/l TDS (USGS 1974). The quality of the water in the coal seam is described in the various coal mine PAPs and the annual monitoring reports on the file with the WDEQ/LQD and was summarized by the USGS (1988). Based on 379 samples from the Wyodak-Anderson coal aquifer, the median concentration of TDS is 1,310 mg/l. Baseline data from the proposed Rocky Butte Mine (see location on map 3) lists average TDS concentrations of 1,210 and 2,120 mg/l reported by Carter and Wyodak, respectively (BLM 1992a). Specific conductance of water from the 25 discharge points in the adjacent Marquiss Field averaged 826 umhos/cm (54 samples) or approximately 550 mg/l (assuming TDS is roughly equivalent to .667 times the specific conductance). Available data suggests that the very shallow wells yield a calcium or magnesium sulfate water. As depth increases, calcium and magnesium ions give way to sodium. The sulfate is replaced, at least in part, by bicarbonate so that the deeper wells yield a sodium bicarbonate type water (USGS 1966). Wells penetrating coal seams or other carbonaceous deposits often yield both water and gas (primarily methane). Water quality analyses for over 72 Fort Union wells are displayed in the appendix. In addition to this data, samples have been collected from the 25 discharge points in the Marquiss Field semi-annually since December 1992. These samples represent waters being pumped from approximately 60 Wyodak wells. The average specific conductance for these discharges is 826 umhos/cm (ranging from 562 to 1,060 for 54 samples).

The quality of the water in the coal seam is described in the various coal mine PAPs and the annual monitoring reports on the file with the WDEQ/LQD and was summarized by the United States Geological Survey (USGS 1988). Based on 379 samples from the Wyodak-Anderson coal aquifer, the median concentration of TDS is 1,310 milligrams per liter (mg/l). Baseline data from the proposed Rocky Butte Mine (see location on map 3) lists average TDS concentrations of 1,210 and 2,120 mg/l reported by Carter and Wyodak, respectively (BLM 1992a). Specific conductance of water from the 25 discharge points in the adjacent Marquiss Field averaged 826 micro mhos per square centimeter (umhos/cm) (54 samples) or approximately 550 mg/l (assuming TDS is roughly equivalent to .667 times the specific conductance).

The Tongue River/Lebo consists of sandstone lenses in a predominantly shale and siltstone matrix (USGS 1988). Thick coal beds occur in the upper part of the Lebo Shale member (USGS 1974). Wells in the Tongue River/Lebo unit generally yield adequate quantities for domestic and livestock use if a sufficient thickness of saturated sandstone lens(es) is penetrated. The thick sequence of shales underlying the Wyodak coal in the vicinity of the existing mines hydrologically isolates the lower aquifers from impacts due to dewatering associated with mine activities and coal bed methane production in the Wyodak coal aquifers. As with the other Fort Union aquifers, recharge is primarily from inflow at outcrop areas. Groundwater flow is generally northward. Water quality is as described above in the Wyodak.

The Tullock aquifer consists of fine- to medium-grained sandstone beds and thin coal beds interbedded with siltstone, shale, and carbonaceous shale (USGS 1988). The sandstone beds in the Tullock tend to be somewhat coarser and more massive than the overlying Tongue River/Lebo members of the Fort Union Formation. The Tullock is separated from the overlying members of the Fort Union Formation by a leaky confining layer (Lebo shale). The Tullock crops on the west along the Bighorn uplift and on the east, east of the Little Powder River, in a series of dissected ridges (USGS 1987). Yields of 200 to 300 gpm are available from the Tullock, making this zone attractive for municipal and industrial uses. Most of the wells for mine facilities are completed in this aquifer. Recharge to the Tullock is from leakage from overlying strata and infiltration along the outcrop areas.

The alluvial aquifers consist of unconsolidated sand, silt, and gravel and underlie floodplains and the bordering terraces of streams in the area. Thicknesses are mostly less than 50 feet. Alluvium overlying formations of tertiary age (Fort Union and above) in the central part of the Powder River Basin is mostly fine- to medium-grained. Coarser deposits occur in the valleys of the Belle Fourche, Cheyenne, Powder, and Little Powder rivers (USGS 1973). Yield from the alluvium is a function of grain size and grain-size distribution. Recharge is from surface infiltration and discharge from underlying strata. Local groundwater movement dominates in these systems and is along the drainage in a down-stream direction. Water quality in alluvium within the Powder River Basin is quite variable with ranges in TDS concentrations from 100 to over 4,000 mg/l. Common ranges are from 500 to 1,500 mg/l (USGS 1973). Analyses from 8 wells completed in alluvium within the project area have an average TDS concentration of 2,232 mg/l, ranging from 467 to 6,610 mg/l (appendix).

A complicating problem exists in predicting groundwater movement and chemical quality in the Powder River Basin. Local leakage between aquifers can occur due to poor well completion techniques and to corrosion of casing in old wells where poor quality water was initially cased off (USGS 1974). In addition to the actual well completions, the Powder River Basin as a whole has been extensively drilled in the course of mineral exploration; plugging the test holes is also of some concern. This type of communication has not been identified but could occur to some degree within the project area.

Table 4, taken from Lowry and others (USGS 1986b), shows trace metal concentrations in groundwater within Coal Area 50, which is the Powder River Basin and includes the project area.

Surface Water

The Lighthouse project area is within the Belle Fourche and Cheyenne River drainages. The Belle Fourche River flows generally to the northeast. It originates and drains an area underlain by continental deposits of shale, sandstone, and coal. The channel is relatively narrow, has a silt and clay bottom, and in places is grass covered. Natural stream flow is primarily from thunderstorms and snowmelt. The groundwater table is intercepted in many reaches; however, very little groundwater is contributed to stream flow.

The Cheyenne River and its tributaries (primarily Little Thunder and Black Thunder creeks) in and near the project area generally flow southeast. The Cheyenne River and its tributaries in this area are ephemeral in nature and are generally underlain by continental deposits of shale, sandstone, and coal as is the Belle Fourche River.

Surface water data (daily discharge, annual peak discharge, water quality, sediment, biology) is available from a few USGS stations near the project area. In addition, the mines down stream have collected some additional data.

Surface water quality in the area is generally suitable for livestock. Table 5 shows water quality criteria as it relates to livestock, agricultural, and domestic use. Table 6 contains water quality data from the Belle Fourche River just downstream of the project area.

TABLE 4
TRACE METAL CONCENTRATIONS OF GROUNDWATER IN COAL AREA 50

Dissolved Trace Metal	Number of Analyses	Number of Analyses Exceeding Drinking Water Standards	Percent of Analyses Exceeding Drinking Water Standards	Drinking Water Standards ($\mu g/m^3$)	Median Value ($\mu g/m^3$)	Maximum Analyzed Value ($\mu g/m^3$)
Arsenic	154	1	0.6	50[a/]	1	120
Barium	95	1	1.0	1,000[a/]	100	1,100
Cadmium	165	1	0.6	10[a/]	2	17
Chromium	116	0	0.0	50[a/]	10	50
Copper	123	0	0.0	1,000[b/]	1	104
Iron	366	56	15.3	300[b/]	100	120,000
Lead	165	6	3.6	50[a/]	2	180
Manganese	257	100	38.9	50[b/]	40	4,800
Mercury	122	0	0.0	2[a/]	0.4	1.5
Selenium	159	4	2.5	10[a/]	1	31
Zinc	141	0	0.0	5,000[b/]	20	1,800

SOURCE: USGS 1986b.

[a/]National interim primary drinking-water standards (U.S. Environmental Protection Agency 1977).
[b/]National secondary drinking-water regulations (U.S. Environmental Protection Agency 1979).

TABLE 5
WATER QUALITY CRITERIA[a]

USE SUITABILITY	CONSTITUENT[b]			
	SODIUM	CHLORIDE	SULFATE (mg/l)	TOTAL DISSOLVED SOLIDS
LIVESTOCK				
Good	---	---	< 500	< 1,000
Fair	---	---	500 - 1,000	1,000 - 3,000
Poor	2,000	---	> 1,000	> 3,000
IRRIGATION				
Good	< 60%[c]	< 200	< 200	< 500
Fair	30 - 75%	200 - 550	500	500 - 2,000
Poor	> 75%	> 550	> 1,000	> 2,000
DOMESTIC	< 115	< 250	< 250	< 500

[a] **SOURCE:** McKee and Wolf 1963; US EPA 1976; USGS 1985.

[b] All values are in milligrams per liter (mg/l) unless as noted.

[c] Sodium absorbtion ratio (SAR) is expressed as: $\frac{Na \times 100}{K + Na + Mg + Ca}$ (MEQ/L)

TABLE 6
CHEMICAL ANALYSES OF WATERS FROM THE BELLE FOURCHE RIVER BELOW RATTLESNAKE CREEK NEAR PINEY, WYOMING

SITE DESCRIPTION: Belle Fourche River below Rattlesnake Creek. Site located just below the Hilight Road. USGS Site ID 06425720.

LOCATION: North latitude 43-59-04, west longitude 105-23-16.

DRAINAGE AREA: 495 square miles.

PERIOD OF OPERATION: November 6, 1975 through April 13, 1983.

PARAMETER	UNIT	NUMBER OF SAMPLES	MEAN	MAXIMUM	MINIMUM
Water temperature	°C	59	12.31	23.5	0.0
Discharge	cfs	102	13.14	1,060.0	0.0
Specific conductivity	umhos/cm	43	3,962.00	8,000.0	1,100.0
pH	standard units	38	7.91	8.1	7.6
Total organic carbon	mg/l	5	9.64	16.0	6.4
Calcium *	mg/l	36	270.00	530.0	95.0
Magnesium *	mg/l	36	171.00	530.0	35.0
Sodium *	mg/l	36	400.00	1,200.0	100.0
Potassium *	mg/l	36	16.00	45.0	6.4
Chloride *	mg/l	36	20.00	55.0	4.1
Sulfate *	mg/l	36	1,957.00	5,400.0	510.0
Fluoride *	mg/l	36	0.45	0.9	0.2
Silica *	mg/l	36	3.80	9.4	0.2
Silver *	µg/l	10	1.10	1.0	2.0
Barium *	µg/l	4	87.50	100.0	50.0
Beryllium *	µg/l	9	7.90	10.0	0.0
Boron *	µg/l	36	151.00	810.0	50.0
Cadmium *	µg/l	10	2.40	10.0	0.0
Chromium *	µg/l	10	5.00	20.0	0.0
Copper *	µg/l	10	3.10	7.0	1.0

PARAMETER	UNIT	NUMBER OF SAMPLES	MEAN	MAXIMUM	MINIMUM
Iron *	µg/l	36	77.60	410.0	10.0
Lead *	µg/l	10	3.90	21.0	0.0
Manganese *	µg/l	14	234.00	800.0	59.0
Molybdenum *	µg/l	5	2.20	4.0	0.0
Nickel *	µg/l	10	3.40	6.0	1.0
Arsenic *	µg/l	1	0.00	0.0	0.0
Strontium *	µg/l	3	2,367.00	3,400.0	1,800.0
Vanadium *	µg/l	4	.325	1.0	0.0
Zinc *	µg/l	10	20.40	40.0	4.0
Aluminum *	µg/l	6	36.70	100.0	10.0
Lithium *	µg/l	8	114.00	300.0	34.0
Selenium *	µg/l	10	1.00	2.0	0.0
Uranium *	µg/l	3	9.23	17.0	1.7
Total dissolved solids	mg/l	33	3,046.00	7,870.0	809.0
Mercury *	µg/l	10	0.15	0.5	0.0

* Total dissolved.

Average annual runoff within the Belle Fourche and Cheyenne River drainages is 10 acre-feet per square mile (USGS 1986b). Table 7 displays estimated peak discharges for streams in the Lighthouse project area.

TABLE 7
ESTIMATED PEAK DISCHARGE FOR AREA STREAMS
(in cfs)

Creek	Drainage Area (square miles)	Recurrence Interval (yrs)					
		2	5	10	25	50	100
Hay Creek T. 46 N., R. 71 W., section 30	96	439	1,037	1,530	2,377	3,294	4,204
West Fork Hay Creek T. 44 N., R. 72 W., section 11	6	131	310	467	725	1,026	1,309
Wild Horse Creek T. 45 N., R. 73 W., section 12	52	346	819	1,213	1,884	2,622	3,346
Threemile Creek T. 46 N., R. 72 W., section 27	41	317	748	1,110	1,724	2,403	3,067
School Section Draw T. 47 N., R. 72 W., section 16	6	137	324	487	757	1,069	1,365
Rattlesnake Creek T. 46 N., R. 71 W., section 8	10	173	408	612	950	1,338	1,707
Hoe Creek T. 47 N., R. 72 W., section 2	59	365	864	1,278	1,985	2,670	3,523

The primary contaminant in most of the surface waters within the Powder River Basin is sediment. Sediment concentrations are naturally high in the plains streams of the basin and can be aggravated by man's activities. Any surface-disturbing activity or activity which reduces watershed cover (vegetation) can increase erosion thus influencing sediment concentrations and loads. Erosion occurs locally in three forms: sheet erosion, gully erosion, and channel/stream bank erosion. Sheet erosion can usually be managed by minimizing surface disturbance and maintaining a good vegetative cover. Gully erosion occurs in the steeper terrain underlain by sedimentary rocks common in the plains portions of the area. The Wasatch and Fort Union formations are particularly susceptible to gully erosion. This type of erosion is difficult to control once initiated. The gully growth is a function of water discharge magnitude and duration which is in turn a function of watershed slope and surface roughness or cover. Gullies can be controlled by controlling discharge and, conversely, sustained or reactivated through increases in discharge over the equilibrium state. Gully erosion follows a threshold pattern. Once gully erosion has occurred, even control of the discharge back to the previous equilibrium level will not stop the growth of the gully. Stream bank and channel erosion are controlled by stream dynamics. Changes in peak flows, sediment load, or base flow can all cause changes in channel morphology.

On most of the drainages, sediment concentration increases in a down-stream direction; however, sediment yield per unit area decreases. This decrease in yield per unit area is caused by decreasing gradients and wider, better-developed floodplains.

WILDLIFE

The EA area is composed of gently rolling sagebrush/grassland, dissected by intermittent drainages. The majority of the area is private surface; therefore, access for wildlife surveys is limited. Existing wildlife information comes from records of the Wyoming Game and Fish Department (WGFD), U.S. Fish and Wildlife Service (FS), energy companies, and the BLM.

The Belle Fourche River is an interrupted stream through most of the project area. This river contains nongame fish such as carp, suckers, shiners and dace. Wetland areas include livestock ponds, ephemeral streams, and playa lakes.

The project area contains winter/yearlong and yearlong antelope range and yearlong mule deer range in the south central portion. Other game species include sage grouse, ducks, geese, and mourning doves.

Raptors that occur in the area include golden eagles (25 nest sites), ferruginous hawks (12 nest sites), red-tailed hawks, Swainson's hawks, prairie falcons, great-horned owls, and burrowing owls. Bald eagles occur in the area during the winter; however, no bald eagle nests have been documented. Nongame mammals include black-tailed prairie dog, coyote, red fox, and raccoon. Badgers, bobcats, and muskrats are the only known furbearers that occur in the area.

There is only one known sage grouse strutting ground within the EA boundary. Because of the large amount of private land and access restrictions, additional leks may occur.

There are no known threatened or endangered plant or animal species habitat in the area.

VEGETATION RESOURCES

Vegetation in the project area is predominantly of the sagebrush/grassland type. Riparian vegetation occurs in limited sites along the Belle Fourche River, minor drainages, and near reservoirs. A very limited amount of dryland agriculture occurs, mostly along Wyoming 59 south.

SOILS

Soils in the Lighthouse project area are dominated by three major soil series--Renohill clay loam, Ulm clay loam, and Arvada clay loam. Small amounts of Wibaux and Sear soils are present (Soil Conservation Service 1955).

The Renohill series occurs on bedrock-controlled hillslopes and ridges. The soil is moderately deep and is formed in residuum from soft, calcareous shale interbedded with sandstone and siltstone. Renohill soils are well drained, with medium to rapid runoff, and slow permeability.

Ulm soils are deep and well drained. They are formed in calcareous alluvium from sedimentary rock. The Ulm series occurs on relict alluvial fan aprons, terraces and piedmont toe slopes. The Ulm series exhibits medium runoff and moderate to slow permeability.

The Arvada soils are formed in slopewash alluvium and pedisediment derived from sodic shales. Located on old terraces, fan piedmonts or fan aprons, are deep and well drained. Runoff is generally medium to rapid, with permeability being very slow.

Wibaux and Sear soils are generally associated with clinker outcrops. They are deep, well-drained soils formed in weathered sediments derived from clinker. Located on hillslopes, knolls, and ridges they are somewhat excessively drained. Runoff is medium; permeability is moderate to very rapid.

These are general soils descriptions only and are intended to give an overall picture of soil resources in the Lighthouse project area. Soils naturally occur in a complex mosaic of series and phases covering a wide range of characteristics. For more detailed site-specific planning, additional soils information is available in the mine permit applications for the mine permit areas for Caballo, Belle Ayr, and Caballo Rojo coal mines (Carter 1985; AMAX 1988; and Mobil 1985). Broader information can be obtained from the Soil Survey (Reconnaissance) of Campbell County Wyoming (SCS 1955). Field work was completed in 1993 on a third order soil survey of southern Campbell County. This survey is not yet compiled for publication, but additional infor-

Campbell County. This survey is not yet compiled for publication, but additional information is available at the USDA, Soil Conservation Service office in Gillette, Wyoming.

LAND USE AND TRANSPORTATION

In the Lighthouse project area, less than 1% of the surface is administered by the BLM, about 5% is owned by the state of Wyoming, and the remaining 94% is private surface (maps 1 and 2).

The primary land uses in the project area are oil and gas production, clinker quarrying, and cattle grazing with some sheep use. The southern portion of the project area is on the Durham Meat Company's ranch which raises buffalo (bison) for meat production.

Recreational land use in the proposed project area includes hunting for mule deer and pronghorn antelope which are common in the area.

Existing oil and gas fields are scattered throughout the project area, and several coal mines border the project on the east.

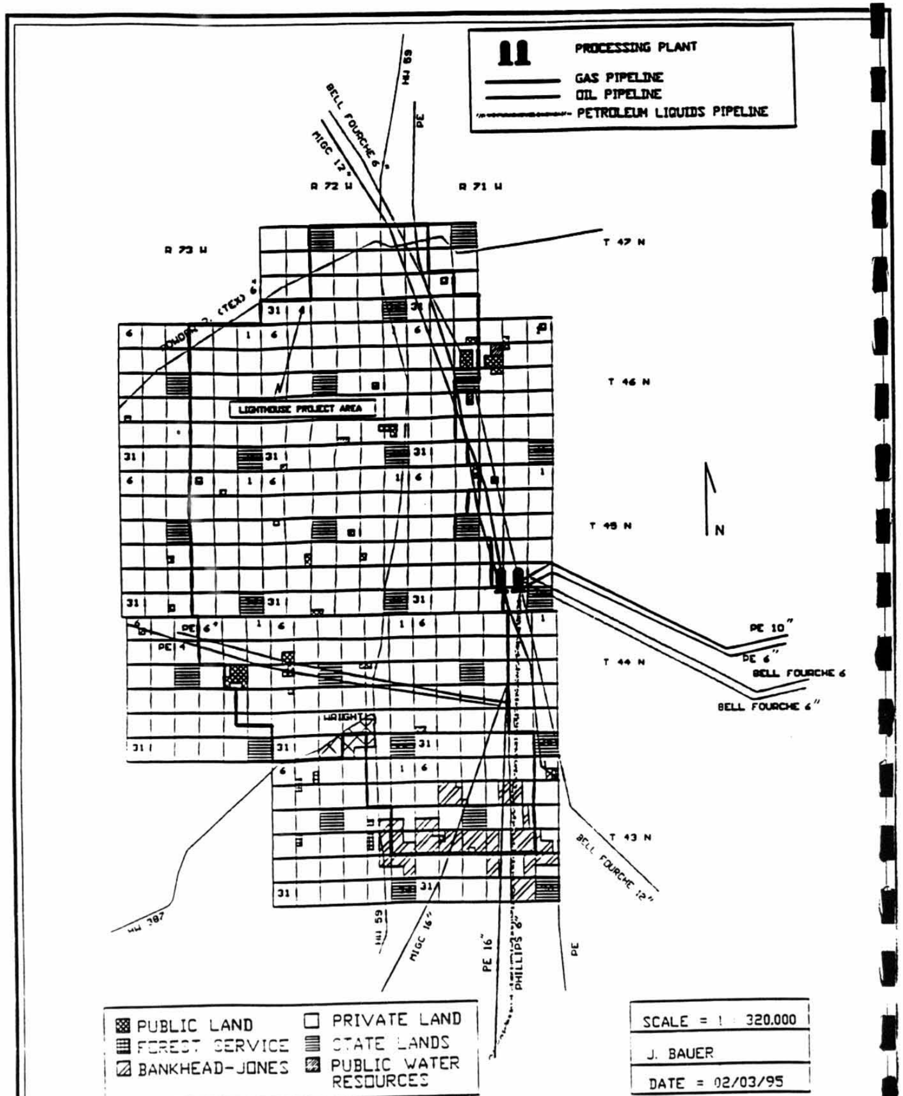
Existing major transportation corridors and networks in the area or adjacent to it include the principal north-south and east-west state highways, one major railroad line, and numerous oil and gas pipelines (map 5).

CULTURAL RESOURCES

Paleoindian sites dating to the earliest recognized cultures have been found and excavated in the vicinity of Gillette. The Lighthouse project is a short physical distance from Gillette, and no barriers to travel separate the areas. In the area, 47 sites have been recorded (table 8). Several sites have multiple components such as prehistoric lithic scatters associated with historic trash dumps. Not all sites produce diagnostic artifacts or datable materials.

Of the 47 sites, four are recommended eligible to the National Register of Historic Places (NRHP): 48 CA 258, a stone circle complex; 48 CA 792, an occupation site; 48 CA 1570, the route of the Sawyer Wagon Road Expedition; and, 48 CA 1312, a stone circle and occupation site.

One unusual condition applies to this project--the presence of bison bone usually indicates prehistoric cultural use. However, buffalo have been raised domestically in this area since 1922, when the Marquiss family obtained the first animals from a herd in South Dakota. Today, the herd numbers several hundred animals which can be seen at the Durham Ranch.



MAP 5
Pipelines, Ownership, Highways and Project Area

While Class III (100% as compared to sampling) cultural resource inventory covers only 4.5% of the total project area, it represents 8.4% of the federal mineral estate. Some 25,200 acres within the project have been subject to cultivation and development mainly for irrigated or sub-irrigated hay meadows. While such lands tend to have relatively high potential for cultural sites, these lands are also subject to repeated disturbance which destroys sites. A scant 338 acres of such lands have been inventoried for cultural resources; however, no sites have been found. The greater portion of such disturbed surface acreage corresponds to coal-only mineral estate. Therefore, unless unique conditions apply, cultivated and disturbed lands will be exempted from further cultural inventory requirements for this project.

TABLE 8
CULTURAL AND TEMPORAL SITE SUMMARY

SITE TYPES	NUMBER	TEMPORAL ASSOCIATIONS	NUMBER
Lithic	13	Archaic	1
Stone circle (single)	2	Middle Archaic	1
Stone circle	(2+) 4	Late Archaic	4
Quarry	3	Late Prehistoric	7
Camp/occupation	4	Protohistoric	1
Rock cairn	1	Historic	18
Sheepherders monument	1		
Sheepherders camp	2		
Historic debris	8		
Homestead	3		
Structure (school)	1		
Homestead complex/ranch	0		
Historic constructs			
Bridge	1		
Depressions	1		
Wagon mine	1		
Historic trail	1		
TOTAL Site Components	**47**	**TOTAL Prehistoric Components**	**14**
		TOTAL Historic Components	**18**

No Native American special interest sites are known to occur in the project area.

RECREATION

Recreational opportunities in the proposed Lighthouse project area are primarily shaped by the fact that a majority of the surface ownership is in private hands; therefore, public access is limited. Given this, the recreational qualities of the area are expected to be similar to the adjacent Marquiss CBM field. The environmental analysis of the

Marquiss project (BLM 1992b) identified sport hunting as the principal recreational land use within the project area. Hunting for pronghorn antelope, mule deer, and white-tailed deer is one of the significant recreational values of the area. The Marquiss EA also identifies mourning dove, sage grouse, waterfowl, and cotton-tailed rabbit as being available for harvesting.

CLIMATE

The climate of the eastern Powder River Basin is semi-arid with average annual precipitation ranging from 14 to 16 inches. In the Lighthouse project area 30% to 40% of the annual precipitation usually occurs in June, July, and August. Only 10% of the annual precipitation occurs in December, January, and February (Martner 1986).

Average annual temperature for the study area is approximately 46° F, with July being the warmest month and January the coldest (BLM 1979).

Regionally, winds come mainly from the west and northwest. Average annual wind speeds range from 9.2 to 13.1 miles per hour, with the highest wind speeds in the winter and spring when gusts frequently reach 30 to 40 miles per hour (BLM 1979).

There are few topographical obstructions that hamper pollution dispersion. The area frequently experiences temperature inversions such as low mixing heights and low wind speeds that hinder pollutant dispersion (PEDCo 1983).

AIR QUALITY

The background TSP concentration annual geometric mean for the region is about 15 micrograms per cubic meter ($\mu g/l^3$). In and near cities, towns, and mines, particulate levels are significantly higher than background levels (BLM 1985). Regulatory agencies assume that the background concentration of suspended particulates smaller than 10 microns (PM-10) is also about 15 $\mu g/l^3$ (BLM 1992a).

Air quality monitoring information shows that rural background concentrations of sulfur dioxide is 1 $\mu g/l^3$ (annual arithmetic mean), and the annual arithmetic mean for nitrogen oxide is 2 $\mu g/l^3$ (BLM 1985).

Visibility of more than 60 miles is common, with significant reductions in visibility related to weather (BLM 1985).

SOCIOECONOMICS

The project area is in Campbell County, Wyoming, in the Powder River Basin. Wyoming Highway 59, which connects Gillette (on Interstate Highway 90) to the north with Douglas (on Interstate Highway 25) to the south, runs through the project area.

Gillette, located about 20 miles north of the northern edge of the project area via Wyoming 59, is the major community in, and the county seat of, Campbell County. Wright, located in southern Campbell County at the intersection of Wyoming 59 and Wyoming Highway 387, is near the southern edge of the project area.

In 1993, Campbell County had a population of 32,801, according to the Campbell County Economic Development Corporation (CCEDC 1995). The 1994 populations of Gillette and Wright were estimated at 20,892 and 1,357, respectively (CCEDC 1995). [Note: Campbell County 1990 population estimates from this source do not agree with the 1990 Census population estimates for the county. The 1990 census estimated the Campbell County population at 29,370, compared with an 1990 population estimate of 32,663 by the county (CCEDC 1995).

Production of minerals (coal, oil, and gas) comprises the largest part of Campbell County's economic base. More than 80% of the coal produced in Wyoming comes from Campbell County, and Wyoming is the top coal producing state in the United States. Campbell County also produces about one-fourth of the oil produced in Wyoming each year. Table 9 shows the state assessed mineral valuations for Campbell County and the state of Wyoming for the state's fiscal year 1993.

TABLE 9
MINERAL VALUATIONS FOR CAMPBELL COUNTY IN FISCAL YEAR 1993[a]

	County Total	Wyoming Total	Percent of State Total
Mineral valuation	$ 1,104.6 million	$ 3.62 billion[b]	30.5
Coal valuation	718.6 million	1.12 billion	64.0
Oil valuation	363.7 million	1.39 billion	26.0
Natural gas valuation	20.4 million	.87 billion	2.4
Sand and gravel valuation	1.9 million	6.30 billion	30.0

[a]Source: WDR 1993; for the state of Wyoming, fiscal year 1993 was July 1, 1992 through June 30, 1993.

[b]Includes bentonite, trona, uranium, and other mineral valuations which are not produced in Campbell County.

Agriculture is also an important part of Campbell County's economic base. According to the Campbell County Economic Development Corporation (1995), the major agricultural products grown in the county are cattle and sheep. The county rates sixth in the state for cattle production and fifth for sheep production. In terms of area, agriculture is the primary land use in the county.

In 1992, the average total employment for Campbell County was 19,378. Employment in the mineral development sector was estimated at 4,574 in 1992 (Wyoming Department of Administration and Information 1994). Employment in the farm sector in 1992 was estimated at 618 for the county. The average 1992 unemployment rate for Campbell County was 5.8%, down from 6.4% in 1990 but up from 5.6% in 1991 (WDAI 1994). The average unemployment rate for the state was 5.6% in 1992.

Per capita income in Campbell County averaged $19,806 in 1992, compared with an average 1992 per capita income of $18,631 for the state of Wyoming (WDAI 1994). Total personal income for the county in 1992 was approximately $606.5 million, compared with a 1992 total personal income for the state of approximately $8.7 billion (WDAI 1994). Total 1992 county personal income earned from all mining (including oil and gas extraction) was approximately $251.8 million, representing 41.5% of the total personal 1992 income for the county (WDAI 1994). Total personal income in the county's agricultural sector was approximately $10.9 million in 1992, which is approximately 1.8% of the 1992 personal income for the county (WDAI 1994).

Based on information published by the CCEDC (1995), there were approximately 7,464 housing units in Gillette, and 492 housing units in Wright as of December 1994. The average cost of a three-bedroom home in 1994 was $80,542. The typical rent for a two-bedroom unfurnished apartment was $340 in 1994, not including utilities. As of October 1994, the overall vacancy rate in Gillette for all types of housing was approximately 2% (Gillette Department of Community Development 1995).

Governmental services available in Campbell County include county government, law enforcement, fire protection, roads and bridges, infrastructure and maintenance, solid waste disposal, medical and emergency services, a public school system, a community college, and a county library.

VISUAL RESOURCES

The entire project and surrounding area is designated as visual resources management (VRM) Class IV; that is, the landscape in its natural state is common in the area and consists of rolling hills with exposed clinker knobs. Dryland vegetation covering most of the area consists of grasses and shrubs. The landscape has been modified by construction of highways, county roads, and private roads used by the public.

Oil and gas wells and related facilities are common throughout the project area as are power lines for domestic and oil field use. Because most structures are relatively small and scattered throughout the project area, the proposed project would retain a rural, open character.

CHAPTER 4
ENVIRONMENTAL CONSEQUENCES

INTRODUCTION

This chapter analyzes the impacts of implementing the Proposed Action which is to approve the APDs to allow drilling, completing, and operating approximately 200 CBM wells in the eastern Powder River Basin of central Campbell County, Wyoming over a five-year time period. Up to 100 of these wells would be drilled on federal minerals. This impact analysis also discusses the impacts on other activities in the project area. Table 10 displays the assumptions used in the following analysis of the environmental consequences.

Environmental impacts associated with CBM projects have also been analyzed by the BLM for [western] Campbell and [eastern] Johnson counties, and for the Marquiss, Pistol Point, and Rawhide Butte EAs (BLM 1990, 1992b, 1992c, 1992d).

IMPACTS OF THE PROPOSED ACTION

Geology and Mineral Resources

Coal production occurs in surface mines to the east of the project area. The methane gas contained in the coal seam is generally released into the atmosphere before or during mining. The only impact the proposed CBM project would have on the coal seam is to pump off water in the area of the well bore and produce the previously trapped methane gas. Gas volumes are estimated to be from 73 million mcf to 730 million mcf.

Developing the Lighthouse project would not impact other mineral resources in the area. Oil and gas are traditionally produced from geologic formations several thousand feet below the coal seam. The salable minerals, primarily clinker, sand, and gravel, are produced on the surface. No locatable mineral ore deposits are known to exist in the project area. Developing the existing minerals in the project area would be covered under pre-existing rights; future conflicts would be dealt with on a case-by-case basis.

TABLE 10
ASSUMPTIONS USED IN IMPACT ANALYSIS

1.	**Number of Proposed Coal Bed Methane Wells**	200 (100 estimated to be federal)
2.	**Maximum Well Density**	0.8 well per square mile
3.	**Depth of Wells**	350 to 1,200 feet
4.	**Number of Compressor Stations**	4
5.	**Proposed Project Area**	160,000 acres (Ts. 43-47 N., Rgs. 71-73 W.)
6.	**Amount of Surface Disturbance:**	
	Per well pad	¼ acre
	Per compressor station	1½ acres
	Amount of road per well	¼ acre
	Amount of pipeline per well	¼ acre
7.	**Water Quality**	
	Surface	Improved
	Subsurface	No impacts
8.	**Water Discharge**	40 discharge points; 5 wells per discharge point; initially 11 gpm; average 7 gpm, to less than 3 gpm
9.	**Methane Production**	50 to 500 mcf per well per day for 10 to 20 years
10.	**AUMs**	4 acres per AUM

TABLE 10
(continued)

11.	**Socioeconomics**	
	Potential value of methane	$1.03 to $2.00 per mcf
	Estimated potential royalty to government	$4,699,375 to $91,250,000 (100 federal wells over 20 years)
12.	**Employment**	
	Development phase - 5 years	No more than one drill rig operating at any given time
		6 people (spread between drilling, casing, logging, and pipeline construction)
	Production phase (10 to 20 years)	2 full-time employees 2 part-time employees

Water Resources

Surface Water

Impacts to surface water resources could occur in three categories: erosion and degradation of the drainage network, sedimentation, and water quality. Surface discharge of the produced water from the coal bed methane wells in the Lighthouse project area (maximum of 200 wells, including 100 federal wells) would be a maximum average per well of 11 gpm declining to less than 3 gpm at the end of 4 years as shown in figure 4. This discharge would be distributed to approximately 40 discharge points (up to 5 wells per discharge point) with maximum discharges of approximately 50 gpm or 0.11 cfs. This flow (0.11 cfs) represents the average annual runoff from approximately 8 square miles. Assuming that all 200 wells flow into the same drainage basin, this increased flow represents only 0.5% to 2.4% of the two-year, 24-hour flood flows (per square mile) listed in table 7 in chapter 3.

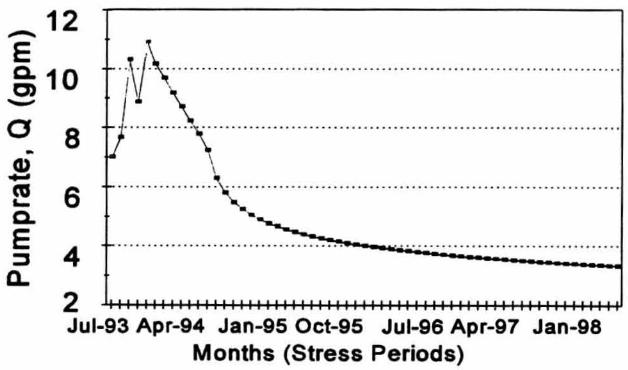


Figure 4

Modeled Pump Rates for the Marquiss and Lighthouse Projects

Pump rates are before January 1995 represent actual mean monthly pump rates for the Marquiss CBM wells. Based on the observed water production in Marquiss project wells, Lighthouse project wells were modeled to produce water at a rate equal to rates observed at Marquiss, then decline with time. The initial fluctuation in the Marquiss pump rates is due to increasing numbers of wells coming into production.

SOURCE: BLM 1995a.

Although these increased flows would not significantly affect peak flows, average daily flows would be increased. This may result in draws and drainages, previously ephemeral, becoming perennial downstream from the discharge points. This increased daily flow is not considered an adverse impact because it would be available for beneficial uses such as livestock and wildlife watering and enhanced vegetation production. The surface landowners would most likely put the discharge water to beneficial use.

Without accelerated erosion the increase in sediment transport and delivery downstream is insignificant. However, significant increases in average daily flows in the smaller, less well-developed drainages could result in degradation of these systems. To mitigate this, American will put the discharged water into existing stream channels or stock ponds in a manner that would not cause increased or accelerated erosion. This has been done effectively at the Marquiss and Rawhide CBM projects by using energy dissipators at the discharge points and by discharging into channels that are well enough developed to handle the increased flows. Cumulative maximum discharge in any given discharge would be limited so as not to exceed the naturally occurring annual peak flow. This is approximately 2.14 cfs per square mile (cfs/sqmi) for the Belle Fourche River drainage above Rattlesnake Creek.

The discharge water quality is good for livestock and fair to good for irrigation use and is better than the naturally occurring water (809 to 7,870 TDS) in the Belle Fourche River just downstream of the project area.

<u>Groundwater</u>

The primary impact to the groundwater resource in the area would be the loss of available hydraulic head, as previously described, in the coal bed methane target formation (the Wyodak-Anderson coal seam). In developing a CBM project, water is removed from the coal aquifer at specific locations, releasing methane gas for collection. This activity would typically result in some loss in hydraulic head in the coal aquifer. The extent and severity of this loss in head is generally not known but can be predicted with the aid of computer simulation of groundwater flow. The short term (1992 through 2004) effects were modeled using repeated computer simulation of the aquifer. Following is a generalized description of this modeling effort. For a full technical description of the modeling effort see *Assessment of Groundwater Impacts Related to the Proposed Lighthouse Coal Bed Methane Project* (BLM 1995a).

Groundwater flow is strongly related to the permeability of the aquifer. Permeability is a measure of ease through which water flows through material. To use a computer model to simulate groundwater flow, permeability and the storage coefficient (amount of water an aquifer material will hold) are required at each spatial location in the model. This information is not available at this level of detail. Therefore, methods are required to estimate these values. In most models currently found in the literature, these values are assumed to be homogeneous throughout the region to be modeled. However, it is well known that water flows through coal as a result of fractures in the coal, and some regions are more highly fractured than others. Permeability, and to a lesser extent, storage coefficient vary regionally. One would anticipate some local areas with high permeability, others with low permeability, with some regional pattern of regularity. This regularity has been observed to be related to the amount of folding in the coal seam, possibly related to stratigraphic and tectonic patterns.

In this modeling effort, the variability of the coal seam from which the methane will be produced was taken into account. Estimates of the average permeability and the variance were obtained from mine permit data along the crop line. It was assumed that permeability was high in areas of folding in the coal. An estimate of the continuity of the permeability was also gained from structure maps in the region. This information together allowed the simulation of several equally likely sets of permeabilities at the 14,896 locations required in areas in and adjacent to the project area. In each simulation of permeability, areas known to have a high degree of folding in the coal were assumed to have higher permeability. Other areas with unknown characteristics were allowed to vary. On one simulation, permeability may have been high in a particular area, while on the next simulation permeability may have been low in the same area. The resulting groundwater flow predictions would be quite different on each of these runs. By repeatedly running the model for the coal seam from which the methane will be produced on several equally likely sets of permeabilities, a range of possible outcomes was obtained, from which groundwater impacts can be estimated.

The Proposed Action was modeled using a groundwater model developed by the U.S. Geological Survey called MODFLOW as described above with the following assumptions.

- ✓ Pump rates from each of the 200 wells in the Lighthouse area averages 7 gpm (11 gpm initially) declining with time over the life of the project to less than 3 gpm (figure 4).

- ✓ The Lighthouse Field will be developed incrementally, with full field development over the five-year development period of the project.

- ✓ The primary recharge is from along the cropline to the east but assumed negligible because of the practically complete interruption due to the mines.

- ✓ The aquifer (Wyodak coal) is an anisotropic (drawdown is not in a uniform cone of depression, but rather an oval), fully confined, non-leaky system averaging 75 feet thick in the project area.

- ✓ Additional stresses to the aquifer system included the 61 wells at the Marquiss field.

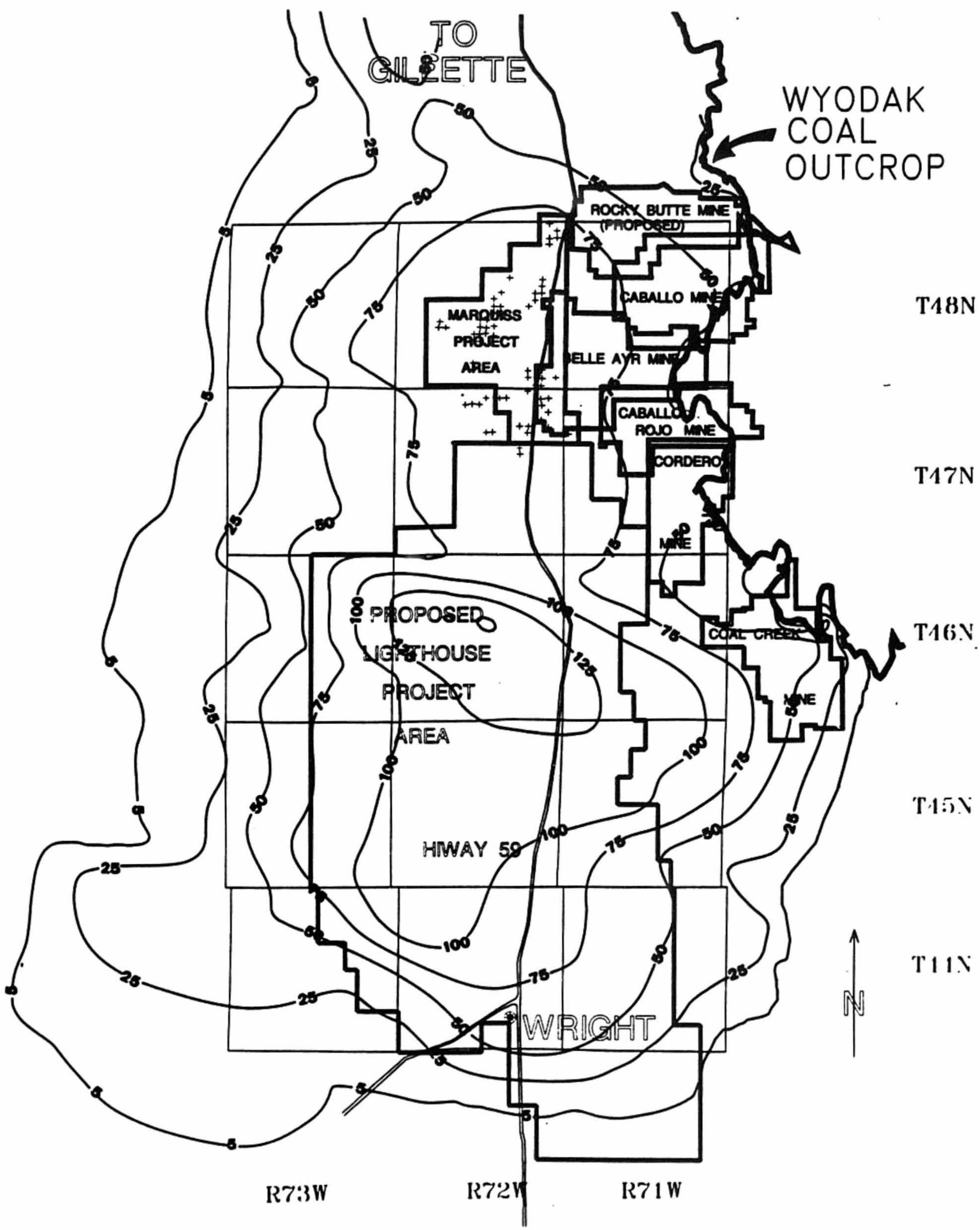
- ✓ The life of the project was projected at 11 years and 8 months (through the year 2004).

- ✓ Transmissivities (amount and ability of water to move through the coal) were simulated and ranged from 450 to 950 gallons per day per foot (g/dy-ft), with a mean of 700.

- ✓ A storage coefficient of 0.005 was used.

The results of the modeling effort are displayed on map 6. This map shows the simulated maximum drawdowns in the year 2004. Impacts to individual water wells completed within the coal would depend on proximity to dewatering wells, depth and completion interval of the water well, and the water well yield required to maintain it as a usable source. There are 87 out of 1,450 of these types of wells. Wells fully penetrating the coal with pumps set low within the coal are likely to be less impacted than those only partially penetrating the coal and with relatively shallow set pumps. This impact is considered insignificant because water will still be available from the coal at a deeper depth and from shallower or deeper aquifers. For individually impacted water wells, see the "Mitigation Measures" section. Water level changes are not expected to occur in the aquifers above or below the coal because it is confined both above and below by a shale layer. Figure 5 is a hypothetical scenario displaying the relationship of a water well completed in the coal and a shallow water well completed in the Wasatch sand.

Isolation of aquifers overlying the coal has been supported by the results of the BLM water monitoring efforts at the nearby Marquiss CBM project. In this instance, the BLM has operated two paired wells (a well completed in the coal and a well completed in the next overlying sand zone) monitoring sites since the beginning of the project and no communication has been seen between the deeper (coal) wells and the shallow (sand) wells, even with the loss of hydraulic head in the coal. In addition, CBM production relies on the integrity of this confining layer, because without it the gas would have been free to escape to the atmosphere and because water leaking downward from shallower layers would make it difficult or impossible to lower the pressure in the coal seam by pumping from it. Information from the coal mines to the east of the project area indicate that the significant sands within the Fort Union Formation are usually located well below the coal and thus not likely to be affected by pumping (BLM 1992b).



MAXIMUM DRAWDOWNS AT YEAR 2004 AS A PRODUCT OF THE CALIBRATED MODEL

Potentiometric Contours

25 ft. Contour Interval

MAP 6

(BLM, 1995 a)

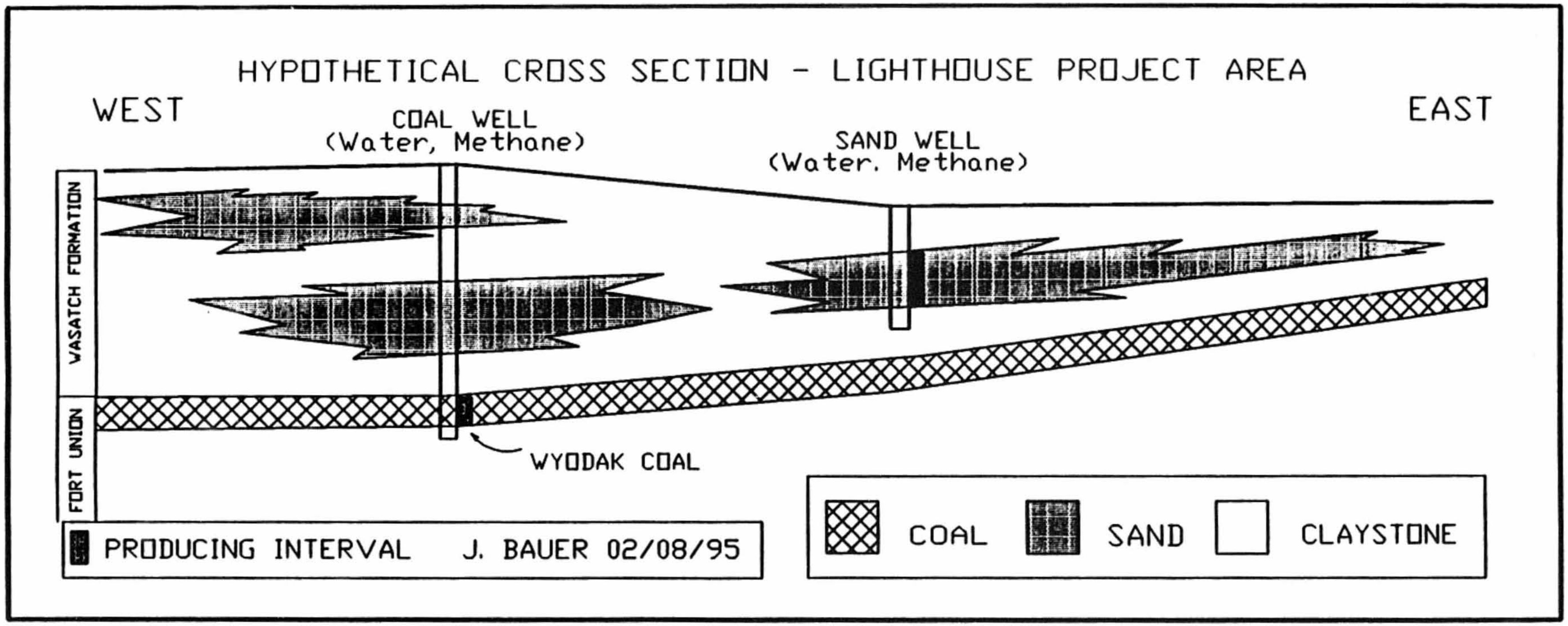

HYPOTHETICAL CROSS SECTION - LIGHTHOUSE PROJECT AREA
WEST
COAL WELL
(Water, Methane)
SAND WELL
(Water, Methane)
EAST
VASATCH FORMATION
FORT UNION
WYODAK COAL
PRODUCING INTERVAL J. BAUER 02/08/95
COAL
SAND
CLAYSTONE

Figure 5

52

Vegetation Resources

A total disturbance of 156 acres during development is estimated for the project area. Assuming 4 acres per animal unit month (AUM) is used as an average production value, then it is estimated that 39 AUMs lost during initial development. This would be the drilling, completion, and pipeline installation for all wells. During the first ten years of the project, 24 AUMs would be lost per year to roads, well pads, and compressor stations once the project is fully developed. Total loss over 10 years is estimated at 279 AUMs. This loss is insignificant and will be offset by increased vegetation resulting from water discharge to the surface and improved livestock distribution with better water distribution within pastures.

Wildlife

Wildlife disturbance due to drilling within the proposed project area should be far less than that which is normally associated with conventional oil and gas drilling operations. Drilling at each of the Lighthouse Field sites is expected to take only two to three days as compared to two weeks for conventional oil and gas wells. Drilling at conventional oil and gas wells normally occurs 24 hours a day; drilling at the CBM wells will not. Truck-mounted drill rigs (water well type) will be used to drill the CBM wells instead of the multicomponent rigs used to drill conventional wells. The drill pad size and road construction requirements are considerably less for these rigs, and American will use existing roads and trails where possible.

Big Game. Drilling and construction activity will temporarily displace antelope and mule deer away from the area until the animals become accustomed to activity. Observations of antelope in the present CBM field suggests that they are somewhat tolerant of human activity most of the year except during the hunting season. Adding roads and increasing access into the area could make it easier for hunters to harvest big game. Antelope and mule deer could be forced away from an area if access and human activity exceeds the animals tolerance levels.

Upland Birds. Drilling and human activity within 2 miles of sage grouse strutting grounds during the breeding and nesting period could cause a disruption or a decline in breeding activity. Permanent activity, or disturbance within ¼ mile of the lek, may cause sage grouse to abandon or move away from the activity. Mitigative measures such as delaying drilling within 2 miles of the lek center until after the strutting and nesting period and not building permanent facilities within ¼ mile of the lek center may prevent sage grouse abandonment. Mourning doves migrating through the area may stay longer with the additional surface water from CBM wells.

Raptors. Most raptors are intolerant of human activity especially during the nesting season. A decline in raptor nesting near CBM wells is expected with new road and

facility construction. Additional power line facilities may cause raptor electrocution or collision fatalities. Burying these lines will eliminate these fatalities.

Waterfowl. Waterfowl numbers would increase if the water produced in the area is stored in reservoirs. The majority of ducks and geese would be present in the spring and fall during migrations. If suitable nesting habitat occurs, some broods may be produced each year. An estimated one brood of ducks or geese would be produced on each one-acre pond. Additional aquatic habitat associated with produced water would increase use and distribution of numerous birds, amphibians, and reptiles presently not occurring due to the lack of water and aquatic vegetation in the area.

Fish. It may be possible to transplant game fish into created ponds in the area. Fishing could produce an added recreational resource presently lacking in the area.

The overall impacts associated with discharging produced water from this CBM project would be positive as far as wildlife are concerned. Vegetation is likely to be enhanced in the vicinity of the individual discharge points, which would provide an additional food source and cover for wildlife. If enough of the produced water is discharged at one location, a wetland habitat may develop. In any case, discharged water from the project would increase the availability of good quality water to wildlife.

Soils

The largest single impact on the soil resource resulting from CBM development is from construction of unsurfaced access roads (50 acres). Soil compaction and runoff from unsurfaced roads can be severe in some site-specific areas.

During well site preparation, vegetation is removed and soil is disturbed and compacted. This activity causes increased soil loss from wind and water erosion.

Soil materials are mixed during underground pipeline construction. When less productive subsoil becomes mixed with the topsoil, overall reclamation potential of the topsoil is reduced.

Estimates of soil loss were computed for the major soil types found in the Lighthouse project area using the Revised Universal Soil Loss Equation (Renard, et al. 1992). This analysis is for comparative purposes only. Actual field conditions can vary greatly depending on site-specific conditions and unusual precipitation events.

When the soil surface is disturbed, the potential exists to increase soil erosion. In general, annual soil loss greater than two tons per acre in semi-arid regions would result in a decrease in soil productivity. Annual projected soil loss from undisturbed native rangeland was determined to be slightly less than 0.50 tons per acre. Computed maximum annual soil loss from disturbed areas ranged from 1.00 to 1.50 tons per acre for the first year after disturbance. After one year, with reestablishment of a 40% vegetation cover, computed annual soil loss would be reduced to 0.50 tons per acre, nearly the same as undisturbed native rangeland. These computations were based on a 5% slope with slopes 400 feet long. In summary, soil loss would be insignificant.

Actual soil loss can be greatly reduced by using erosion control practices. Reclamation practices on the Marquiss project have resulted in very little accelerated erosion and a high level of reclamation success.

Land Use and Transportation

This project is expected to last 10 to 20 years. After that time, the facilities, (including wells) would either be turned over to the surface owner or removed and the area rehabilitated. Remaining facilities would be only those beneficial to the surface owner. The enhanced water and livestock distribution should allow more even use of the forage.

Short-term impacts to grazing as a result of developing the Lighthouse project would be the removal of about ¼ acre of forage at each well location. Pipelines and two-track roads would disturb additional land. Livestock and wildlife would be disturbed during the construction phase.

In the long term, most of the acreage would be returned to production within a few years as the disturbed area is revegetated.

Some positive impacts to grazing are anticipated. The discharged-produced water would aid in distributing livestock and wildlife, providing more temperate water in both winter and summer, and enhancing vegetation diversity and productivity near the discharge points and along discharge drainages.

At the conclusion of the project, wells beneficial for livestock or wildlife use could be turned over to the surface owner, including related roads. Unneeded roads and facilities would be removed and the area rehabilitated.

Cultural Resources

Cultural sites are nonrenewable resources and once disturbed lose much of their preserved information, integrity, and heritage value. Avoidance is preferred because even well pad construction, access roads, collection pipelines, and limited vehicle use have the potential to disturb such sites.

BLM encourages preservation of cultural properties whenever possible; mitigation is undertaken when a direct impact to a significant property cannot be avoided. Inadvertent or unintentional impacts to a significant site may be found to be the developer's responsibility and may require mitigation. Such problems are less likely when the proposed action is properly planned for. When mitigation with a data recovery plan takes place, the effect to the site or cultural property is considered "no effect" or "no adverse effect."

Visual Resources

Changes in the visual character of the landscape due to the proposed activities would be similar, but greatly reduced, to those already in place to accommodate existing conventional oil field activity. Using two-track and existing roads and centralizing separator facilities would minimize the visual impact of the road network. This would allow smaller sheds to be built over each well with only one larger shed at the separator. Buried power lines to each well would reduce the linear element in the landscape.

Recreation

Although the development of roads and well facilities would result in greater physical access to the project area, a majority of this access would be limited to privately owned surface. According to the conclusions drawn from the environmental analysis of the adjacent Marquiss Field (BLM 1992b) project, there should be no significant negative impacts to hunting in the project area since wildlife numbers would not be reduced. Given the potential good quality of discharged water associated with the project, it is reasonable to conclude that the enhanced vegetation and increased water availability would probably have positive effects on all aspects of wildlife and their habitat.

American has stated they will work with landowners in the project area to enhance the use of the good quality, discharged water. This practice would promote the impoundment of discharged water and use for wetlands and/or fisheries development.

Air Quality

A potential source of air pollution associated with CBM development is particulates. The main source of particulates associated with CBM development would be from road, drill pad, and pipeline construction. Emissions from diesel generators and gas compressor stations would also contribute particulates.

An analysis of CBM development related to particulate emissions conducted in 1990 showed that most of the impacts occur within 100 meters of the well site (BLM 1990). The 1990 analysis included particulate production from diesel generators used to pump water from the production well. American will use submersible, electric powered pumps thus eliminating any emissions.

Other air pollutants released by associated diesel engines include sulfur dioxide, nitrogen oxide, and carbon monoxide. CBM development is expected to contribute minimal amounts of any of these pollutants.

Socioeconomics

The impacts on local employment are not expected to be significant. Although as many as 200 wells could ultimately be drilled, the drilling would be phased over a five-year period. Eighteen wells have already been drilled on state and private minerals within the project area. Existing two-track roads would be used wherever possible, which would limit the need for construction of additional roads, and the workers that would be associated with that construction. The wells would be drilled using small truck-mounted water well drills. Drilling each well involves approximately two people for two days. Additional employment of several people would occur during construction of the gas gathering and delivery system. One or two full-time employees would be needed during the production phase of the project for well inspection, maintenance, and service. Finally, abandonment of the project would involve several people to dismantle and remove aboveground facilities and plug the wells.

The impacts to the transportation networks in the project area are not expected to be significant due to the low levels of employment needed for the project. This applys to the construction, operation, and abandonment phases of the project.

The production of the coal bed methane would generate revenue for the state, county, federal government, and private landowners in the form of royalties, severance taxes, ad valorem taxes, sales and use taxes, easements, and rights-of-way. These increased revenues would be realized for the life of the project.

To gain an understanding of the potential economic significance of coal bed methane development in the Lighthouse area, estimates can be made based on available opinion about reservoir characteristics, well performance, and sales expectations.

Although the market for coal bed methane gas is highly volatile, a potential sale price value of $1.03 to $2.00 per mcf over the life of the project is not an unreasonable assumption.

Assuming a Lighthouse well produces 50 to 500 mcf per day with a well life of 10 to 20 years, 200 wells could yield as much as 73 million to 730 million mcf of gas with an estimated sales value of up to $1,460,000,000. Royalties collected from the project's federal wells could range from $4,699,375 to $91,250,000 over the same period.

MITIGATION MEASURES

Water Resources

Surface Water

Discharge points will be approved by a qualified hydrologist to ensure channel stability. The channel will be inspected for signs of accelerated erosion and appropriate mitigation will take place as necessary.

Groundwater

The main effect of the predicted loss in hydraulic head associated with the proposed action is to temporarily reduce or eliminate the available head in nearby water supply wells that are completed in the coal (map 6). Mitigation of these impacts in accordance with state law can be accomplished by replacing water supplies if well yields are reduced below historic levels. Temporary replacement can be accomplished at the cost of the operator with commercially purchased water, with water produced by the operator, or by reimbursing a well owner for increased energy requirements associated with the greater pump lift. Permanent replacement can be accomplished by drilling and completing a replacement well. If mitigation is required, such measures would be developed by the BLM in consultation with the Wyoming State Engineer and the affected landowner.

CUMULATIVE IMPACTS

NEPA requires cumulative as well as site-specific impacts of a proposed federal action be considered as part of the decision-making process. According to the Council of Environmental Quality, cumulative impacts on the environment which can result from identified environmental impacts, including those that are incremental or of low magnitude, must be considered. These "cumulative" impacts should be evaluated in light of other past, present, and reasonably foreseeable future actions in the affected area regardless of what agency (federal or nonfederal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time (40 CFR 1508.7). In the case of the Lighthouse project, concerns center primarily around the cumulative impacts of coal mining, coal bed methane development, oil and gas production, and other known activities that impact water quality and availability in the central Powder River Basin of Wyoming.

Principal past actions that must be considered in the evaluation of the cumulative impacts are those that have affected similar resources and for which the effect is still residual in the environment.

Past resource development actions in and near the proposed project area that may affect resources for which the effect is still residual consists of the oil and gas development in 19 existing oil and gas fields, prior quarrying of clinker for aggregate, and 12 coal mines located east of the project area.

The reasonably foreseeable projects that can be expected in the area of the proposed project are continued coal mining from existing mines, continued drilling of oil and gas leases and their potential conversion to secondary and tertiary recovery. The combination of the proposed CBM wells and these activities should represent only a slight increase in the overall magnitude of cumulative impacts to the area.

Coal mining at the mines nearest the project area is expected to continue for the next 20 years (based on current mine plans). Continued future implementation of this oil and gas development will depend on economic factors. Given that industry has a strong desire to develop the oil and gas leases in the Powder River Basin, this development will most certainly go forward during the next 20 years. Development of the Lighthouse project as described should contribute only small, incremental impacts to the area.

Water Resources

The common, and potentially cumulative impacts to water resources by activities associated with CBM development and those impacts associated with coal mining include withdrawal of water from the coal seam resulting in a loss of head in the coal, and the surface discharge of this produced water.

Impacts associated with mining but not with CBM development include the following:

Changes in Groundwater Quality: After mining, the aquifer (Wyodak coal) is replaced with mine spoils which have the potential to change the quality of the aquifer. In CBM development, water is simply being removed; there are no foreign materials being introduced to the system.

Changes in Infiltration Rates and Recharge: In mining, the surface and aquifer are being removed and replaced--complete surface and subsurface disturbance. In CBM development, the aquifer remains essentially undisturbed--the recharge mechanism is unchanged.

Impacts to Aquifers Stratigraphically Above the Coal: The Fort Union and Wasatch formations are assumed to be hydrologically isolated. In mining, the shallower aquifers (the overburden) must be removed to access the coal; therefore, the impacts to these aquifers are significant. In CBM development, these aquifers are essentially undisturbed and, if hydrologically isolated as assumed, not impacted.

Subcoal Fort Union Aquifers: It is unlikely that CBM development will impact the subcoal aquifers; therefore, there will be no cumulative impact.

Surface Water

The two main issues relating to cumulative surface water impacts are: possible changes in runoff rates and possible changes in surface water quality.

Some studies indicate that infiltration rates are initially smaller on reclaimed lands than on premining lands. A weighted average reduction of 29% has been found, with this reduction declining over time until the postmining infiltration rates recover to premining levels (USGS 1988). Since runoff and infiltration rates have an inverse relationship, a reduction in infiltration rates could cause an increase in runoff and streamflows. Assuming that the runoff from reclaimed areas is 29% greater than that from premining areas (based on the change in infiltration rates noted above), the USGS determined that major streams in the Powder River Basin would see runoff increases ranging from 0.4% for the Cheyenne River to 4.3% for Coal Creek. In addition to these predicted increases due to coal mining, the Marquiss and Lighthouse CBM developments would add approximately 5 cfs (2%) of the mean annual flow of the Belle Fourche and Cheyenne rivers.

Surface water quality should not be significantly affected by mining, based on studies conducted by the USGS for the Belle Fourche River Basin (USGS 1986b). Sediment yield should not increase in area streams, even with the added area disturbed by the Lighthouse project. Although reclaimed soils may be more erosive for the first few years after reclamation, the larger sediment production would probably not be delivered to area streams due to sediment deposition as a result of flatter slopes on reclaimed lands and sediment trapping by mandated sedimentation ponds. As described in the "Environmental Consequences" section of this EA, the water discharged as the result of CBM will be of better quality than the naturally occurring surface water in the area.

Groundwater

The cumulative impact of surface coal mining and other activities (including CBM development) on groundwater has emerged as an area of concern during the scoping process and in comments received on coal leasing proposals and the Marquiss coal bed methane project. The WDEQ/LQD is required by the Surface Mining Control and Reclamation Act (SMCRA) and WDEQ/LQD rules and regulations (WDEQ 1980) to as-

sess the potential for cumulative hydrologic impacts of current and anticipated mining on the ground and surface water systems each time a mine permit application or a mine permit revision is made. In 1987, the U.S. Geological Survey, in cooperation with the WDEQ/LQD and the Office of Surface Mining (OSM), conducted a study of the hydrology of the eastern Powder River Basin. The purpose of the study was to provide the hydrologic information needed to perform these assessments. The resulting document, "Cumulative Potential Hydrologic Impacts of Surface Coal Mining in the Eastern Powder River Structural Basin, Northeastern Wyoming," (CHIA) describes the cumulative effects of all current and anticipated mining (as of 1987) on the hydrologic system (USGS 1988). The 1988 CHIA is the most comprehensive basinwide assessment of the potential hydrologic impacts of surface coal mining in the Wyoming Powder River Basin.

During scoping for coal leasing and the Marquiss project, concern was expressed over reliance on this CHIA in assessing groundwater. The scoping comments specifically identified groundwater impact analysis concerns related to two specific evaluation report findings: 1) that "assessments of the hydrologic impacts of mine sites in the Powder River Basin are based on technical data that may not be site specific," and 2) that some CHIA documents in Wyoming are deficient in that not all hydrologic impact projections were based on the most recent technical/baseline information (OSM 1992).

The lack of site-specific data is a surface water data concern in the evaluation report not a groundwater data concern. The evaluation report noted that Wyoming agreed that the "USGS CHIA was site specific to the Belle Fourche River Basin and should not be extrapolated and used area wide" (for surface water impacts).

With respect to the second finding, the evaluation report did not find that the CHIAs were inadequate, but the report cited areas where they could be improved. The evaluation report noted that WDEQ agreed that CHIA analyses must consider the most current information available for each mine in assessing cumulative impacts. The report also suggested a procedure that would "include all the latest baseline information from the probable hydrologic consequences of all mines in the cumulative impact area." As a result of a cooperative agreement signed in 1993, BLM, OSM, the University of Wyoming, and the State Engineer's Office are providing assistance to WDEQ/LQD in the CHIA update process, which is expected to take several years to complete.

The issues raised in the evaluation report do not change the assessment of impacts to water resources described in this EA. This EA describes anticipated impacts using the available information.

Monitoring programs required by WDEQ/LQD and administered by the mining companies have been established in the eastern Powder River Basin. Each mine is required to monitor groundwater levels in the coal itself as well as in shallower aquifers in the area surrounding their operations. There are also requirements for drilling monitoring wells in the backfill areas of the mines in order to record the water level recovery in these areas. In addition to the mine monitoring required by DEQ/LQD, the SEO and the BLM have required water monitoring to be done on coal bed methane projects.

The Gillette Area Groundwater Monitoring Organization (GAGMO) is a voluntary group formed in 1980. The purpose of GAGMO is to assemble and report the hydrologic monitoring data being collected by the coal mining companies operating in the eastern Powder River Basin of Wyoming, from the Buckskin Mine north of Gillette to the Antelope Mine in northern Converse County. Members of GAGMO include most of the companies with operating or proposed mines in that area, the WDEQ, the Wyoming State Engineer's Office, the BLM, the USGS, and the OSM, which joined in 1991. The Dave Johnston Mine near Glenrock is not a member of GAGMO. The Cordero Mine resigned from GAGMO in December 1992.

Each year GAGMO contracts with an independent firm to publish the results of the monitoring for that year. In 1991 GAGMO published two reports--an annual report for 1990 and a 10-year report. The 10-year report, prepared by Hydro-Engineering of Casper, summarized the data accumulated during the last 10 years of monitoring in the Powder River Basin. According to that report, 646 monitoring wells were operated at 21 coal mines in 1990 (Hydro-Engineering 1991). The 21 sites included active and inactive mines and unmined leases. Data for the Cordero Mine are not included in the GAGMO 1993 annual report but were included in the 10-year report and in annual reports prior to 1993.

A major groundwater issue is the extent of the loss in hydraulic head in the coal and shallower aquifers in the area surrounding the mines. Most of the monitoring wells included in the GAGMO 10-year report (578 wells out of 646 total) are completed in the coal beds, in the overlying sediments, or in sand channels or interburden between the coal beds. These holes range from 9 feet to 420 feet deep. Figure 6, taken from the GAGMO 10-year report, shows the changes in water levels in the coal seams after 10 years of monitoring (Hydro-Engineering 1991). This map shows the area where actual decline in hydraulic head in the coal seam has been greater than 5 feet in 10 years, in comparison with the predicted worst-case 5-foot decline derived from groundwater modeling done by the mines. WDEQ/LQD policy is to have the mining companies determine the extent of the 5-foot reduction in head.

In general, reduction in hydraulic head as a result of mining activities in the coal does not extend east of the mines because the mines are located on or near the coal outcrop line. The actual 10-year, 5-foot reductions have not exceeded the predicted worst-case reduction in any of the mines. In most cases, the reduction in hydraulic head is well within the mines' predicted worst-case reduction.

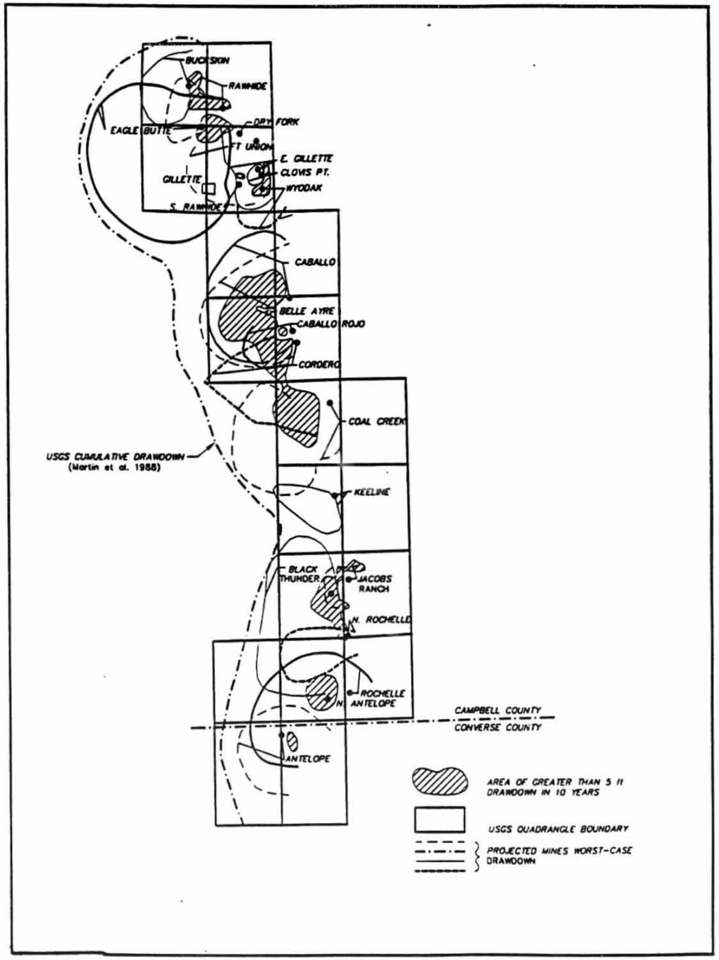


Figure 6: Comparison Between the 1990 Cumulative Drawdowns and the Mines' Worst-Case, and the USGS Predicted Cumulative Drawdowns (Modified from Hydro-Engineering, 1991)

The actual 5-foot loss of hydraulic head levels are also well within the cumulative hydraulic head predicted by the USGS in the Powder River Basin CHIA (USGS 1988). This study predicts the approximate area of 5-foot or more water-level decline in the Wyodak coal aquifer which will result from "all anticipated coal mining." "All anticipated coal mining" (as referred to in the CHIA) includes 16 surface coal mines operating at the time the report was prepared and 6 proposed mines. The proposed mines include two which are now producing, one which was inactive but is now producing, and the proposed Rocky Butte Mine. The study assumes that water-supply wells completed in the coal may be affected as far away as 8 miles from mine pits, although at this distance the effects were assumed to be minimal.

The CHIA indicates that there are about 3,000 wells in the area subject to impact by current and anticipated mining in the basin. About 1,200 of these wells are outside the actual mine areas and will not be removed by mining. About 1,000 of these wells are for domestic or livestock uses, and about 200 wells supply water for other uses. The remaining 1,800 wells are used by coal mining companies. About 1,700 wells are monitor wells only; the other 100 are used for water supply and dewatering at mine sites.

Of the 1,200 water-supply wells subject to impact, about 580 are completed in the Wasatch aquifer, about 100 in the Wyodak coal aquifer, and about 280 in strata below the coal. There is no completion data available for the rest of these wells (about 240). They could be completed in any of the above aquifers.

Since the actual 10-year loss in hydraulic head (or water-level decline) lies well within the cumulative levels predicted by Martin et al. (USGS 1988), the cumulative impacts to water wells have not reached the levels described in that report.

The additional groundwater impacts that would be expected as a result of the Lighthouse and Marquiss coal bed methane developments (map 3) would be additive in nature and would extend the area experiencing a loss in hydraulic head to the east. The area between the CBM fields and the mines would be subjected to the cumulative impacts of these two distinct activities. The overlapping impacts of the two activities would be additive. For example, at a point (or a well) that is experiencing a loss of hydraulic head of 50 feet caused by CBM activities and a loss of head of 5 feet as a result of coal mining activities, the total loss of hydraulic head will be 55 feet. In this example this is the point where the 5-foot contour line from the 1988 CHIA predicted cone of depression resulting from the mine activities intersects the 50-foot contour line of the predicted cone of depression resulting from CBM activities.

Wildlife

Cumulative impacts to wildlife occur as a result of surface disturbance. The total portion of unreclaimed land at any one time is much less than that of the proposed project area. Cumulative impacts to big game species, sage grouse, raptors, and prairie dog towns could occur; however, these impacts should not be significant due to the small percentage of land involved and the short duration of development activities.

Similarly, the cumulative impacts to range forage should be temporary, short term, and minimal in relation to the total available rangeland within the proposed project area.

Socioeconomics

The cumulative socioeconomic impacts of the proposed project associated with other energy development projects and activities in Campbell County would be insignificant because facility construction and operation of the proposed project are on a small scale. The Lighthouse project's small permanent work force (two full- and two part-time employees) is an insignificant impact compared to other energy development employers in Campbell County.

The Lighthouse project's potential financial return to Campbell County and the state of Wyoming in the form of mineral severance taxes, royalties, and taxes will contribute significantly to the county.

RESIDUAL IMPACTS

The primary long-term residual impact of the proposed action would be withdrawal of water from the coal aquifer. Given that there is clear evidence for the opportunity of recharge and/or recovery in the affected aquifer this impact should diminish with time. What is uncertain is how efficiently this recharge will occur in the proposed project area.

CHAPTER 5
CONSULTATION AND COORDINATION

SCOPING PROCESS

On August 16, 1994, the BLM sent a letter to all surface owners in the potentially affected area of the proposed project. This letter briefly described the project, the scoping process, and set a schedule for public meetings to receive comments on the proposal. BLM issued a press release on August 23, 1994 regarding American Oil and Gas' proposal to develop the Lighthouse project. The press release contained a brief description of the proposed project and announced the time and location of the scoping meetings. Public meetings were held with the Powder River Basin Resource Council at the Campbell County Public Library (August 23, 1994); with landowners at the Holiday Inn in Gillette (August 25, 1994); and, a general public meeting was convened at the Gillette Holiday Inn, September 1, 1994. In addition to these scoping meetings, tours of existing coal bed methane production facilities at American's Marquiss Field were conducted by the BLM and American on August 23, 1994 and August 26, 1994.

A letter was sent to all participants on September 23, 1994, stating what environmental analysis process would be followed by the BLM.

On October 27, 1994, the BLM issued a news release extending the comment period to November 30, 1994. This was necessitated by American Oil and Gas' desire to increase the size of the proposed project area and the need for more time for the BLM to collect additional hydrological and geological data.

The primary concern raised by the public involved potential negative impacts of the coal bed methane development on water availability to domestic water wells in the proposed project area and any potential reduction of surface water quality.

CONSULTATION AND COORDINATION

Concurrent with the scoping of the Lighthouse project, the BLM was in the process of developing a model and database system. This system was to help analyze the potential hydrologic impacts associated with withdrawn water from the coal aquifer being mined by surface coal mines to the east.

Given that the BLM, other federal agencies, and WDEQ were already gathering data to put into a database to support coal development and management, Casper District office personnel intended to use the database to calibrate analysis of the cumulative impacts to the groundwater of the area.

The following agencies and groups have provided input to this EA.

Federal Agencies

U.S. Fish and Wildlife Service

State of Wyoming

Governor's Planning Office
Public Service Commission
Game and Fish Department
State Engineer's Office
State Historic Preservation Office
State Department of Environmental Quality, Water Quality Division

Citizens Groups and Regional Societies

Powder River Basin Resource Council

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Joe Meyer, Soil Scientist	Soils, climate, and air quality
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APPENDIX
CHEMICAL ANALYSES OF WELLS AND SPRINGS IN THE POWDER RIVER STRUCTURAL BASIN AND ADJACENT AREAS, CAMPBELL COUNTY, WYOMING[a/]

LEGEND

Geologic Age		Geologic Unit	
	Name	Mnemonic Code	Name
Locally present aquifers	Holocene	ALVM	Alluvium
	Tertiary	INTV	Intrusive Rock
	Oligocene	WRVR	White River Formation or Group
===========	==========	=====	==============
Wasatch/Fort Union	Eocene	WSTC	Wasatch Formation
	Paleocene	FRUN	Fort Union Formation
		TGRV	Tongue River Member or Fort Union Formation
		TULK	Tullock Member of Fort Union Formation
===========	==========	=====	==============
Lance/Fox Hills	Cretaceous	CRCS	Cretaceous System
	Upper Cretaceous	CODY	Cody Shale
		FXH	Fox Hills Formation
		FRNR	Frontier Formation
		LNCE	Lance Formation
===========	==========	=====	==============
Aquitard		LWIS	Lewis Shale
		MVRD	Mesaverde Formation or Group
		PIRR	Pierre Shale
===========	==========	=====	==============
Dakota	Lower Cretaceous	CLVL	Cloverly Formation
		FLRV	Fall River Formation
		INKR	Inyan Kara Group
		LKOT	Lakota Formation
		MWRY	Mowry Shale
===========	============	=====	==============
Aquitard	Upper Jurassic	GPSP	Gypsum Spring Formation*
		MRSN	Morrison Formation
		SNDC	Sundance Formation
	Upper Triassic	CGTR	Chugwater Formation or Group
	Lower Triassic	GSEG	Goose Egg Formation
		SPRF	Spearfish Formation
	Lower Permian	CSPR	Casper Formation
			Fort Union Formation
		MNKT	Minnekahta Limestone
		MNLS	Minnelusa Formation
		OPCH	Opeche Shale
		TSLP	Tensleep Sandstone
===========	============	=====	==============
Madison	Upper Mississippian	CRLS	Charles Formation of Madison Group
		MDSN	Madison Limestone
		MSNC	Mission Canyon Limestone
	Lower Mississippian	LDGP	Lodgepole Limestone
		PHSP	Pahasapa Limestone
	Upper Ordovician	RDRV	Red River Formation of Bighorn Group
	Middle Cambrian	FLTD	Flathead Quartzite or Sandstone
===========	==========	=====	==============
Aquitard	Precambrian	PCMB	Precambrian Erathem

*Now designated Middle Jurassic by the USGS.

APPENDIX

CHEMICAL ANALYSES OF WELLS AND SPRINGS IN THE POWDER RIVER STRUCTURAL BASIN AND ADJACENT AREAS, CAMPBELL COUNTY, WYOMING[a]

Sample Location	Date of Collection	Aquifer	Well Depth or Interval sampled (feet)	Specific Conductance (microsiemens)	pH	Temperature (C°)	Dissolved Solids (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Alkalinity as bicarbonate (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Fluoride (mg/l)	Nitrate as nitrogen (mg/l)	Silica (mg/l)	Boron (µg/l)	Iron (µg/l)
42N 69W 07BAC	07/08/68	125FRUN	120	951	8.4	---	613	32	17	161	7.8	396	186	4	0.4	---	7.7	60	550
42N 70W 05DDD	07/09/68	124WSTC	233	7,660	8.1	12.0	8,200	414	919	720	6.8	254	5,940	35	1.0	---	37.0	60	1,300
42N 70W 32AA	07/08/68	124WSTC	280	1,460	8.4	13.0	929	66	30	241	7.4	745	185	23	.6	---	8.2	30	700
42N 71W 26BBC	07/15/68	124WSTC	110	2,290	8.2	11.0	1,720	179	35	310	7.8	197	1,080	7	.1	---	8.5	40	170
42N 74W 06AC	06/29/68	124WSTC	225	1,310	---	10.0	146	146	33	112	6.9	210	515	16	.3	---	7.6	20	80
43N 69W 19AB	08/07/68	125FRUN	170	2,080	8.5	11.0	1,490	61	30	385	9.2	333	828	4	.6	---	5.6	10	490
43N 70W 11DA	08/07/68	124WSTC	45	1,720	8.1	11.0	1,440	244	66	83	18.0	227	885	3	.9	---	28.0	---	30
43N 71W 21ADB	06/22/78	124WSTC	100	1,550	8.2	11.5	1,320	96	23	310	8.0	240	750	9	.1	0.01	9.6	---	150
43N 71W 21ADB	06/22/78	124WSTC	200	1,700	8.8	12.5	1,560	110	29	350	11.0	207	940	8	.3	.02	7.6	---	40
43N 72W 11BDD	08/11/49	124WSTC	485	---	8.1	---	314	31	6	---	---	267	50	11	---	---	---	---	---
43N 72W 11BDD	03/16/49	124WSTC	160	---	7.3	---	2,700	506	163	---	---	271	1,800	13	---	---	---	---	---
43N 72W 11BDD	08/05/49	124WSTC	240	---	8.2	---	1,780	206	65	---	---	169	1,150	13	---	---	---	---	---
43N 72W 16CC	07/09/68	124WSTC	345	2,130	8.5	12.0	1,790	340	100	68	8.6	318	1,100	2	.0	---	17.0	100	890
43N 72W 18BD	07/09/68	124WSTC	261	1,360	8.3	12.0	1,030	202	46	54	7.2	247	584	3	.1	---	15.0	90	400
43N 72W 21CA	07/09/68	124WSTC	550	617	8.3	13.0	367	12	3	137	2.3	389	1	12	.7	---	8.3	70	210
43N 72W 36BCC	06/21/78	125FRUN	693	2,300	7.9	11.5	2,570	310	180	180	9.5	320	1,600	4	.3	.20	6.5	---	120,000
44N 70W 28CBC	08/07/68	124WSTC	261	1,180	8.5	11.0	785	40	10	221	5.2	366	306	13	1.0	---	8.9	10	440
44N 71W 10DD	07/08/68	124WSTC	124	2,040	7.9	11.0	1,710	299	110	74	7.0	242	1,080	6	.4	---	14.0	60	30
44N 72W 15BA	05/10/66	124WSTC	145	2,960	7.2	---	2,660	448	157	122	13.0	340	1,730	7	1.0	---	17.0	310	1,030
44N 73W 35CC	10/14/68	124WSTC	205	1,520	7.8	11.0	1,070	75	17	238	3.3	118	672	3	.3	---	6.8	10	30
45N 71W 02AAA	06/05/68	124WSTC	155	1,740	7.5	13.0	1,240	100	26	268	6.3	361	630	19	.8	---	7.4	60	2,300
45N 71W 05BAD	10/21/77	125FRUN	400	1,300	7.3	10.0	792	30	12	240	10.0	790	62	41	1.1	---	5.4	160	700
45N 72W 36BCC	06/21/78	124WSTC	218	4,150	7.7	10.0	3,760	460	250	300	12.0	410	2,500	16	.3	.03	11.0	---	3,200
45N 74W 17CB	06/29/68	124WSTC	259	2,070	7.8	---	1,520	136	19	309	5.1	82	1,000	5	.4	---	7.2	20	60
45N 75W 34BB	10/11/68	124WSTC	160	755	7.9	10.0	487	92	36	26	4.1	358	135	2	.2	---	15.0	10	970
46N 72W 01BCC	07/15/68	124WSTC	90	3,600	8.2	11.0	3,660	594	218	167	14.0	296	2,480	19	1.9	---	12.0	110	8,800
46N 72W 27AAC	08/30/68	124WSTC	125	1,060	8.0	12.0	705	55	8	176	5.2	268	308	12	.5	---	8.4	30	---
46N 73W 06DDD	07/12/68	124WSTC	233	1,740	8.1	13.0	1,350	210	48	160	7.1	308	755	5	.1	---	11.0	40	320
46N 73W 34CCD	07/19/68	124WSTC	200	1,820	8.1	12.0	1,300	130	31	271	4.9	573	555	12	.3	---	8.8	50	610
46N 74W 09CB	10/09/68	124WSTC	281	1,090	7.9	---	726	34	8	195	1.9	120	410	9	.4	---	7.4	10	40

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Sample Location	Date of Collection	Aquifer	Well Depth or Interval sampled (feet)	Specific Conductance (microsiemens)	pH	Temperature (C°)	Dissolved Solids (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Alkalinity as bicarbonate (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Fluoride (mg/l)	Nitrate as nitrogen (mg/l)	Silica (mg/l)	Boron (µg/l)	Iron (µg/l)
46N 75W 09BD	10/09/68	124WSTC	400	1,400	7.4	12.0	983	44	11	250	2.6	88	604	18	.2	---	9.4	20	520
46N 76W 10DA	10/09/68	124WSTC	90	2,340	7.9	12.0	1,890	198	123	231	4.4	274	1,160	15	.2	---	10.0	120	20
47N 72W 07CBC	11/05/80	124WSTC	---	1,901	8.0	12.0	1,300	55	14	360	11.0	293	680	25	.3	.00	13.0	30	1,600
47N 72W 07CBC	11/12/80	124WSTC	---	2,733	7.7	10.0	2,160	270	67	320	16.0	329	1,300	9	.1	.01	13.0	80	190
47N 72W 07CBC	11/11/80	124WSTC	---	2,218	9.4	10.0	1,480	42	23	380	63.0	317	780	26	.2	.01	7.4	300	90
47N 72W 07CBC	10/24/79	124WSTC	---	1,590	8.8	11.0	1,220	31	20	350	9.0	268	670	9	.2	.01	2.5	60	10
47N 72W 07CBD	10/04/77	124WSTC	---	2,220	6.8	10.5	1,620	200	63	190	6.7	290	860	7	---	.04	---	50	40
47N 72W 07CBD	10/05/77	124WSTC	---	1,420	8.3	10.0	1,000	31	13	280	5.1	293	520	7	---	.01	---	50	30
47N 72W 07CBD	11/10/80	124WSTC	---	1,849	6.7	13.0	1,600	310	100	100	13.0	817	620	23	.2	.01	28.0	110	2,000
47N 72W 07CBD	11/11/80	124WSTC	---	975	6.5	11.0	629	150	41	19	6.9	646	64	4	.3	.01	23.0	80	1,800
47N 72W 07CBD	11/12/80	124WSTC	---	2,100	6.5	10.0	1,390	260	70	140	11.0	1,499	430	12	0.01	.01	18.0	90	810
47N 72W 07CBD	11/12/80	124WSTC	---	1,350	6.9	10.5	891	140	37	140	12.0	820	99	32	.1	.01	21.0	80	710
47N 72W 07CBD	11/12/80	124WSTC	---	1,400	7.0	14.0	852	140	44	130	9.2	880	31	28	.4	.01	20.0	100	3,800
47N 72W 07CBD	10/10/76	124WSTC	156	1,150	7.4	10.5	799	43	11	230	5.7	501	260	10	---	.03	---	80	10
47N 72W 07CBD	10/09/76	124WSTC	156	1,020	7.9	12.0	649	35	8	200	4.9	475	98	11	---	.01	---	70	10
47N 72W 07CBD	10/10/76	124WSTC	156	960	7.7	10.5	630	32	8	200	4.9	496	95	12	---	.11	---	70	10
47N 72W 07CBD	10/09/76	124WSTC	156	980	7.9	10.5	632	27	8	210	6.1	514	77	11	---	.02	---	80	10
47N 72W 07CBD	10/09/76	124WSTC	156	1,000	7.6	11.0	645	30	8	210	5.0	542	75	11	---	.02	---	80	10
47N 72W 07CBD	10/22/76	124WSTC	---	1,700	10.7	10.5	1,060	66	20	300	28.0	501	400	9	---	.01	---	60	200
47N 72W 07CBD	10/09/76	124WSTC	172	980	7.6	14.5	619	27	8	200	4.6	484	100	15	---	.03	---	120	10
47N 72W 07CBD	01/19/77	124WSTC	172	2,400	7.1	24.5	2,010	---	---	---	---	475	1,100	22	---	.01	---	---	---
47N 72W 07CBD	08/04/77	124WSTC	172	1,660	7.8	17.0	1,160	61	23	300	14.0	380	550	14	---	.10	---	170	110
47N 72W 07CBD	10/29/76	124WSTC	172	2,400	7.2	29.5	1,230	110	27	310	45.0	1,930	260	13	---	.02	---	350	300
47N 72W 07CBD	10/23/76	124WSTC	172	1,850	7.8	13.0	---	---	---	---	---	---	---	---	---	---	---	---	---
47N 72W 07CBD	08/04/77	124WSTC	156	1,650	7.4	17.0	1,400	150	44	230	19.0	260	790	11	---	.01	---	230	1,200
47N 72W 07CBD	01/20/77	124WSTC	156	1,950	7.3	19.0	1,700	220	49	220	15.0	337	940	13	---	.01	---	230	3,500
47N 72W 07CBD	01/19/77	124WSTC	156	---	---	---	1,540	190	60	190	7.5	347	820	7	---	.01	---	60	580
47N 72W 07CBD	08/04/77	124WSTC	---	2,650	9.4	18.0	2,320	350	19	280	33.0	50	1,500	19	---	.10	---	2,400	30
47N 72W 07CBD	08/04/77	124WSTC	156	---	7.3	12.0	877	41	11	260	5.0	430	350	7	---	.04	---	120	60
47N 72W 07CBD	01/04/78	124WSTC	---	2,100	7.0	17.0	1,080	98	24	380	7.9	1,120	65	8	---	.02	---	100	1,900
47N 72W 07CBD	01/04/78	124WSTC	---	2,500	7.0	15.0	1,670	160	40	460	9.3	1,710	140	7	---	.05	---	110	8,500
47N 72W 07CBD	08/05/77	124WSTC	156	1,490	7.2	11.5	978	51	12	270	4.8	380	440	7	---	.01	---	60	740
47N 72W 07CBD	11/15/77	124WSTC	---	3,200	6.5	11.0	1,670	180	49	560	9.4	1,810	120	7	---	.10	---	140	27,000
47N 72W 07CBD	08/05/77	124WSTC	156	---	---	---	719	29	7	230	3.8	551	200	7	---	.10	---	60	1,500
47N 72W 07CBD	08/05/77	124WSTC	156	1,080	6.8	11.5	688	31	7	230	3.9	600	110	8	---	.10	---	60	1,300
47N 72W 07CBD	10/05/77	124WSTC	---	1,440	8.5	10.0	985	46	11	300	5.4	390	470	7	---	.02	---	70	10
47N 72W 07CBD	02/14/78	124WSTC	---	2,400	9.3	84.0	1,480	170	14	180	98.0	427	980	50	---	.96	---	2,900	500
47N 72W 07CBD	01/17/78	124WSTC	156	---	7.7	55.0	1,650	140	26	280	100.0	200	950	48	---	.03	---	2,800	60
47N 72W 07CBD	12/01/78	124WSTC	---	1,700	6.8	24.0	1,030	190	53	130	9.2	1,140	0	0	---	.04	23.0	140	720
47N 72W 07CBD	03/22/79	124WSTC	---	1,580	7.1	11.5	1,170	200	55	140	7.9	990	240	15	.2	.10	22.0	80	860

Sample Location	Date of Collection	Aquifer	Well Depth or Interval sampled (feet)	Specific Conductance (microsiemens)	pH	Temperature (°C)	Dissolved Solids (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Alkalinity as bicarbonate (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Fluoride (mg/l)	Nitrate as nitrogen (mg/l)	Silica (mg/l)	Boron (µg/l)	Iron (µg/l)
47N 72W 07CBD	12/01/78	124WSTC	---	1,780	6.7	10.0	1,590	240	79	140	8.5	730	690	9	---	9.30	24.0	80	1,700
47N 72W 07CBD	07/11/79	124WSTC	---	1,200	7.7	12.5	746	34	8	250	5.4	790	41	9	.3	.01	8.3	60	20
47N 72W 07CBD	07/11/79	124WSTC	---	1,400	6.7	10.0	1,050	190	60	78	6.6	730	310	5	.2	.10	41.0	100	3,200
47N 72W 07CBD	03/07/80	124WSTC	---	2,140	6.6	18.0	1,200	290	86	34	8.0	1,158	170	4	.2	.04	34.0	80	1,400
47N 72W 07CBD	03/07/80	124WSTC	---	2,160	7.0	14.2	1,300	300	85	38	11.0	1,134	270	4	.2	.10	36.0	80	1,100
47N 72W 07CBD	03/07/80	124WSTC	---	1,910	6.7	22.0	1,070	250	75	42	8.6	1,158	76	7	.2	.02	35.0	160	1,200
47N 72W 07CBD	08/13/80	124WSTC	---	1,080	6.8	13.8	---	180	58	44	6.1	---	170	8	.3	.00	13.0	130	3,700
47N 72W 07CCA	11/12/80	124WSTC	---	3,183	6.8	12.0	2,240	220	54	510	13.0	1,268	750	39	.1	.01	23.0	100	720
47N 72W 07CCA	07/10/79	124WSTC	---	---	---	---	1,610	120	30	370	6.5	360	890	8	.2	.10	10.0	70	510
47N 72W 07CCA	11/07/80	124WSTC	---	3,200	7.8	50.0	2,450	92	100	520	86.0	430	1,400	41	1.0	.00	18.0	2,000	590
47N 72W 07CCA	03/23/79	124WSTC	---	2,500	7.8	10.5	2,090	350	20	290	13.0	300	1,200	57	.2	.10	12.0	130	220
47N 72W 07CCA	06/10/81	124WSTC	---	---	---	---	2,370	310	68	470	12.0	1,256	860	14	.1	---	17.0	290	540
47N 72W 07CCA	03/23/79	124WSTC	---	2,500	7.3	10.5	2,440	230	40	410	9.3	460	1,200	9	.1	.10	12.0	260	600
47N 72W 07CCA	05/09/80	124WSTC	---	3,600	6.5	24.5	3,390	430	100	580	23.0	1,463	1,500	8	.1	.02	21.0	140	6,800
47N 72W 07CCA	07/10/79	124WSTC	---	1,100	7.7	11.5	799	27	7	250	4.2	510	200	50	.3	.10	7.2	70	1,200
47N 72W 07CCA	07/11/79	124WSTC	---	1,050	8.0	11.5	693	28	7	220	6.7	530	130	30	.3	.10	8.7	60	480
47N 72W 07CCA	07/11/79	124WSTC	---	2,300	7.4	11.5	1,840	160	37	390	9.6	490	980	8	.1	.10	11.0	50	1,600
47N 72W 07CCA	10/24/79	124WSTC	---	1,990	6.8	11.3	1,440	170	33	340	8.7	1,195	260	23	.2	.00	12.0	90	2,100
47N 72W 07CCA	07/11/79	124WSTC	---	2,250	7.7	10.5	1,730	140	34	370	10.0	420	940	8	.1	.04	15.0	50	9,100
47N 72W 07CCA	07/10/79	124WSTC	---	850	7.9	---	558	19	5	200	4.0	570	25	15	.4	.10	8.5	70	170
47N 72W 07CCA	03/23/79	124WSTC	---	1,370	7.8	10.5	948	43	11	280	5.1	430	320	67	.3	.10	7.9	90	730
47N 72W 07CCA	03/23/79	124WSTC	---	1,200	7.8	11.0	802	56	7	230	27.0	510	160	61	.3	.10	8.8	260	110
47N 72W 07CCA	10/25/79	124WSTC	---	2,240	6.6	10.7	1,950	200	43	420	9.9	792	870	8	.2	.00	12.0	70	1,300
47N 72W 07CCA	12/05/79	124WSTC	---	3,170	7.1	12.7	2,380	300	52	500	10.0	1,755	550	33	.2	.02	17.0	110	48,000
47N 72W 07CCA	03/07/80	124WSTC	---	4,000	6.8	---	2,810	310	84	560	18.0	1,365	1,100	43	.1	.01	17.0	90	1,700
47N 72W 07CCA	03/07/80	124WSTC	---	4,960	7.5	59.4	3,400	240	75	600	120.0	80	2,200	95	2.3	.09	16.0	4,400	30
47N 72W 07CCA	05/06/80	124WSTC	---	1,600	8.2	14.0	1,140	49	12	310	5.5	195	640	12	.2	.02	8.5	10	40
47N 72W 07CCA	08/15/80	124WSTC	---	3,980	7.0	48.0	---	400	83	520	36.0	---	1,800	36	.4	.01	29.0	1,900	40
47N 72W 08CBB	07/10/79		---	1,450	7.6	13.5	952	110	31	160	8.1	590	330	9	.1	.10	11.0	100	10
47N 72W 09BDC	01/06/78	124WSTC	---	1,150	7.4	11.0	1,950	230	100	180	9.6	170	1,200	5	---	.01	---	60	1,300
47N 72W 09DBC	10/07/76	124WSTC	---	2,600	7.4	11.0	2,520	290	92	310	11.0	138	1,500	5	---	.01	---	80	1
47N 72W 12BCC	10/08/76	124WSTC	---	1,900	7.8	11.0	1,430	81	20	360	5.8	232	810	5	---	.01	---	40	10
47N 72W 17AAB	10/08/76	124WSTC	---	2,400	7.5	10.5	2,040	180	55	320	9.7	17	1,300	5	---	.01	---	40	10
47N 72W 18BBC	10/08/76	124WSTC	---	1,500	7.2	6.5	1,340	170	48	160	11.0	158	760	12	---	.09	---	110	10
47N 72W 18CA	08/18/75	125FRUN	---	2,025	7.1	13.0	1,430	180	52	210	8.3	340	790	7	.1	---	13.0	50	630
47N 72W 18DA	08/18/75	125FRUN	---	1,020	7.9	12.0	697	35	11	210	10.0	515	160	8	.3	---	7.8	60	40
47N 72W 24CD	06/05/68	124WSTC	40	3,590	7.4	11.0	3,420	482	252	173	12.0	273	2,300	50	1.1	---	13.0	130	5,830
47N 73W 08DDC	07/12/68	124WSTC	311	1,200	8.3	11.0	766	33	6	205	2.9	98	457	5	.4	---	7.3	20	80
47N 75W 06DCA	10/10/68	124WSTC	200	1,200	7.4	11.0	773	25	3	220	2.4	78	461	15	.3	---	8.1	20	30
47N 75W 13BCC	10/10/68	124WSTC	355	1,630	7.6	13.0	1,310	225	74	96	5.1	350	720	3	.2	---	10.0	30	40

Sample Location	Date of Collection	Aquifer	Well Depth or Interval sampled (feet)	Specific Conductance (microsiemens)	pH	Temperature (°C)	Dissolved Solids (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Alkalinity as bicarbonate (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Fluoride (mg/l)	Nitrate as nitrogen (mg/l)	Silica (mg/l)	Boron (µg/l)	Iron (µg/l)
47N 76W 26CD	10/09/68	124WSTC	300	1,580	7.6	11.0	1,040	61	10	257	2.6	90	656	5	.4	---	6.8	0	130
48N 69W 11DC	07/11/79	125FRUN	420	1,650	8.4	13.8	1,210	8	3	400	2.6	542	540	8	.7	---	5.8	120	50
48N 69W 22AC	07/11/79	125FRUN	400	1,780	8.4	11.4	1,260	8	3	410	2.6	408	610	13	1.3	---	7.3	90	110
48N 69W 28DCC	03/07/80	111ALVM	40	753	8.5	---	467	84	23	58	4.7	422	74	1	.4	---	13.0	80	60
48N 69W 35ABD	03/07/80	125FRUN	170	1,780	8.7	11.0	1,190	15	5	410	3.6	590	440	7	.7	---	7.3	80	70
48N 70W 17BC	06/20/68	125FRUN	300	2,160	6.8	12.0	1,950	367	81	78	6.7	32	1,360	9	.3	---	35.0	50	670
48N 71W 11BCC	06/20/68	124WSTC	180	1,470	8.2	23.0	924	53	19	305	8.7	1,060	1	5	.9	---	8.2	80	770
48N 71W 34CB	06/05/68	124WSTC	114	2,020	7.3	11.0	1,450	151	51	307	12.0	984	412	10	.9	---	14.0	90	4,860
48N 72W 13AA	06/17/68	124WSTC	122	2,270	7.7	12.0	1,880	300	156	62	8.4	375	1,110	7	1.1	---	14.0	150	180
48N 73W 31AD	07/12/68	124WSTC	305	2,000	7.9	11.0	1,520	151	31	285	6.0	180	948	2	.2	---	7.8	30	20
48N 75W 06BAA	07/11/68	124WSTC	300	658	8.1	12.0	384	6	1	135	1.4	220	111	12	.4	---	7.9	20	140
48N 75W 14BD	07/27/76	124WSTC	195	510	8.8	13.0	312	5	1	110	1.1	223	61	16	.6	.10	7.4	40	90
49N 69W 07AC	02/08/72	211FXHL	2,700	1,540	8.3	28.5	971	3	1	391	1.6	793	132	30	5.2	.20	15.0	570	30
49N 71W 18DCC	05/26/49	124WSTC	204	514	7.0	---	227	36	19	9	3.2	123	80	4	.8	---	13.0	110	14,600
49N 71W 29DCA	06/04/68	124WSTC	263	1,010	7.8	17.0	655	24	7	213	4.1	437	177	5	.8	.00	9.5	40	---
49N 72W 04AB	08/07/49	124WSTC	387	2,030	7.5	---	1,250	58	45	311	11.0	627	476	21	1.2	---	8.7	70	20
49N 72W 05AAB	06/14/49	124WSTC	120	2,210	7.0	---	1,940	365	114	40	9.2	46	1,370	4	.6	---	12.0	270	11,000
49N 75W 29CAC	01/01/58	125FRUN	2,111	---	8.0	---	1,290	15	9	510	---	1,231	118	34	---	---	---	---	---
49N 75W 31CCC	07/11/68	124WSTC	420	539	8.1	14.0	330	5	0	123	1.2	229	68	10	.8	---	8.6	30	70
49N 75W 32DCC	08/05/58	125FRUN	2,737-2,832	---	8.2	---	1,010	19	5	380	---	781	150	70	---	---	---	---	---
49N 75W 32DCC	08/09/58	211LNCE	5,297-5,362	---	8.5	---	2,630	13	5	997	---	1,256	600	380	---	---	---	---	---
49N 75W 32DCC	08/09/58	211FXHL	5,918-6,050	---	8.4	---	3,200	19	---	1,290	---	1,914	200	720	---	---	---	---	---
49N 75W 32DD	07/11/68	124WSTC	160	442	8.4	11.0	263	3	2	100	1.7	267	1	13	.5	---	9.2	30	130
49N 75W 34CA	07/21/76	124WSTC	515	993	8.8	14.2	646	9	2	190	2.1	180	330	16	.3	.03	7.9	40	90
49N 75W 34CA	07/21/76	124WSTC	520	680	8.7	12.6	---	---	---	---	---	194	---	---	---	---	---	---	---
49N 76W 27AAA	07/11/68	124WSTC	1,000	1,140	8.1	17.0	726	9	2	300	3.3	779	7	10	2.0	---	9.3	110	460
50N 71W 20ADC	05/23/49	124WSTC	6	1,890	7.3	---	1,490	195	112	58	67.0	304	856	8	.9	---	30.0	630	10
50N 71W 21BBB	10/24/74	125FRUN	220	3,700	7.6	10.0	2,790	330	150	380	40.0	753	1,500	11	.5	---	9.8	80	20
50N 71W 27AAC	10/22/74	111ALVM	18	3,020	7.7	10.5	2,180	260	130	290	14.0	443	1,100	160	.5	---	6.7	280	50
50N 71W 27ABA	03/04/75	125FRUN	---	535	8.3	17.1	333	6	1	130	4.7	354	3	5	1.2	.10	8.3	50	---
50N 71W 27BAD	03/05/75	111ALVM	19	7,270	7.5	9.5	6,610	370	520	980	18.0	746	4,300	38	.7	.10	12.0	480	---
50N 71W 27BAD	05/15/75	125FRUN	---	480	7.7	14.0	289	5	2	110	4.0	301	1	8	.9	.02	8.0	40	---
50N 71W 27BCB	05/21/49	125FRUN	540	471	7.7	---	270	8	4	91	2.8	283	3	7	1.0	---	11.0	190	50
50N 71W 28AAC	05/24/76		---	1,550	8.0	14.0	---	160	81	290	21.0	---	1,100	39	.6	---	4.6	---	30
50N 71W 33BAC	10/22/74	125FRUN	152	4,000	7.6	8.5	3,070	290	160	500	23.0	895	1,600	44	.6	---	8.8	120	430
50N 71W 33BAC	10/22/74	125FRUN	65	3,200	7.5	9.5	2,500	380	180	180	23.0	675	1,300	90	.5	---	12.0	120	---
50N 71W 33BAC	03/06/75	111ALVM	26	4,230	7.5	8.0	2,950	370	250	280	16.0	846	1,400	200	.8	.04	13.0	240	---

Sample Location	Date of Collection	Aquifer	Well Depth or Interval sampled (feet)	Specific Conductance (microsiemens)	pH	Temperature (°C)	Dissolved Solids (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Alkalinity as bicarbonate (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Fluoride (mg/l)	Nitrate as nitrogen (mg/l)	Silica (mg/l)	Boron (µg/l)	Iron (µg/l)
50N 72W 08BBB	05/20/49	124WSTC	380	1,180	7.5	---	734	25	14	254	5.6	823	2	8	.8	---	12.0	80	850
50N 72W 14AAA	05/20/76		---	825	7.4	19.0	---	---	---	---	---	---	---	---	---	---	---	40	140
50N 72W 20CAA	05/21/49	124WSTC	160	667	7.6	---	430	85	32	9	5.6	249	149	4	.9	---	17.0	0	270
50N 72W 21AAC	05/25/76		---	950	7.9	38.0	831	2	0	350	3.3	848	7	28	5.4	.01	16.0	190	30
50N 72W 21ACC	06/14/49	124WSTC	210	2,280	7.6	---	1,940	341	150	43	14.0	373	1,170	7	.2	---	22.0	220	3,300
50N 72W 21ACC	05/31/49	211FXHL	3,445	1,830	---	43.9	1,150	5	1	473	5.2	1,217	2	31	8.0	---	20.0	260	10
50N 72W 22CAC	05/31/49	125FRUN	840	1,190	7.7	---	745	50	24	177	7.6	432	238	15	1.4	---	13.0	150	510
50N 72W 26AAC	05/26/76	124WSTC	207	4,000	6.9	12.5	---	---	---	---	---	311	---	---	---	.02	---	100	3,700
50N 72W 26ACB	07/06/76	124WSTC	280	1,220	7.3	14.9	712	30	15	240	7.2	800	6	10	.8	.06	8.8	80	20
50N 72W 26BBB	05/26/76		---	3,000	6.8	12.0	---	500	180	88	16.0	---	1,900	8	.1	---	18.0	160	2,600
50N 72W 28ABB	08/13/76	124WSTC	232	3,100	6.5	13.0	2,830	530	150	46	6.2	274	1,900	8	.5	.01	23.0	110	21,000
50N 72W 34AAA	07/06/76	124WSTC	1,106	604	7.5	21.2	347	11	4	120	5.1	363	2	8	1.0	1.30	10.0	60	170
50N 72W 35BA	05/23/68	124WSTC	340	1,230	7.7	11.0	782	34	19	269	7.3	859	13	7	.6	---	8.5	100	10
50N 72W 35DD	05/09/68	124WSTC	305	4,140	7.3	11.0	4,060	448	443	104	10.0	311	2,880	3	3.2	---	15.0	230	6,000
50N 73W 01AA	08/13/76		---	3,000	7.0	12.5	2,690	530	150	45	6.1	210	1,800	8	.4	---	22.0	120	20,000
50N 73W 27BCB	05/25/76		---	1,700	6.9	10.0	2,150	430	110	86	7.2	363	1,300	24	.4	---	13.0	230	10
50N 74W 25ACC	07/10/68	124WSTC	270	689	8.3	---	415	13	1	158	2.3	444	1	12	.5	---	8.7	60	90
50N 74W 31CB	05/21/68	124WSTC	290	1,740	7.4	11.0	1,220	50	17	312	3.0	123	768	2	.7	---	7.8	20	0
50N 75W 30BD	10/15/68	124WSTC	400	635	7.9	11.0	395	7	2	138	1.5	217	121	9	.8	--r	8.2	20	20
51N 69W 20BD	07/01/68	125FRUN	206	1,980	8.7	---	1,340	28	4	450	4.9	620	530	1	2.8	---	6.9	100	90
51N 69W 20DB	07/01/68	211FXHL	2,250	1,660	8.7	10.0	1,110	18	1	390	3.8	597	384	3	1.8	---	8.0	120	100
51N 69W 34DCB	10/15/71	211FXHL	2,396	1,280	9.0	16.0	824	2	0	320	1.1	545	198	18	4.0	0.10	11.0	170	60
51N 71W 22CDC	06/09/49	124WSTC	SPRING	438	7.7	---	286	53	11	14	11.0	164	79	3	1.0	---	25.0	230	10
51N 71W 23CD	06/28/68	125FRUN	219	1,990	8.1	12.0	1,440	119	65	261	16.0	519	703	8	.6	---	7.7	250	80
51N 71W 29AD	06/28/68	125FRUN	130	1,390	7.3	9.0	1,070	192	47	62	20.0	257	612	3	1.1	---	5.9	960	340
51N 71W 30BAD	06/08/49	124WSTC	SPRING	1,380	7.4	---	1,080	193	56	43	27.0	191	636	3	.9	---	25.0	710	30
51N 71W 32CDC	06/28/68	125FRUN	311	1,620	7.6	14.0	1,020	57	29	320	11.0	1,150	1	10	.9	---	27.0	70	600
51N 72W 22CB	06/06/68	124WSTC	100	1,660	7.5	12.0	1,070	79	38	306	10.0	1,120	73	1	.7	---	12.0	360	370
51N 72W 23AB	11/22/76	125FRUN	1,100	---	7.7	---	3,480	500	220	200	65.0	337	2,300	6	.6	---	21.0	3,200	10
51N 72W 29BDD	05/20/49	124WSTC	34	2,690	7.5	---	2,320	275	204	144	14.0	266	1,480	21	.6	---	19.0	200	2,200
51N 72W 32CCC	09/18/50	124WSTC	433	3,040	7.3	13.5	---	---	---	---	---	424	---	6	.4	---	---	---	45,000
51N 76W 09BB	10/15/68	125FRUN	1,800	1,790	8.4	15.0	1,160	24	3	455	17.0	1,231	0	21	1.1	---	14.0	100	60
52N 70W 02AB	07/01/68	125FRUN	750	1,210	8.8	13.0	781	7	1	300	1.9	629	144	6	1.8	---	7.4	150	70
52N 70W 11CA	06/27/68	125FRUN	635	1,310	8.7	12.0	825	5	5	325	1.9	702	123	10	2.4	---	8.4	180	270
52N 70W 25DB	07/01/68	125FRUN	505	1,390	8.8	12.0	948	5	2	360	2.1	594	266	7	2.6	---	7.9	70	160
52N 73W 25DD	05/14/68	124WSTC	210	437	7.2	12.0	273	58	13	10	1.9	146	100	1	.9	---	16.0	10	1,400
52N 74W 01BA	07/22/76	125FRUN	---	4,080	7.5	12.5	4,050	460	150	570	14.0	268	2,700	6	.1	.04	9.1	100	2,700
52N 75W 17AD	07/17/68	124WSTC	938	831	8.4	16.0	506	10	4	198	3.1	549	1	9	.7	---	10.0	30	40
52N 75W 27CBA	07/17/68	124WSTC	160	679	8.2	11.0	415	6	0	167	1.8	435	1	14	1.6	---	8.2	50	50
53N 70W 13AA	07/05/76	125FRUN	810	1,240	8.3	15.0	755	3	1	290	1.6	577	160	4	1.9	.02	8.5	180	220
53N 70W 21DC	06/27/68	125FRUN	710	1,320	8.8	14.0	833	7	0	340	1.9	763	89	8	2.3	---	9.2	160	240

Sample Location	Date of Collection	Aquifer	Well Depth or Interval sampled (feet)	Specific Conductance (microsiemens)	pH	Temperature (°C)	Dissolved Solids (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Alkalinity as bicarbonate (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Fluoride (mg/l)	Nitrate as nitrogen (mg/l)	Silica (mg/l)	Boron (µg/l)	Iron (µg/l)
53N 70W 026CC	06/27/68	125FRUN	720	1,250	8.7	15.0	790	5	3	309	1.7	655	130	7	3.4	---	8.8	160	120
53N 70W 33BDA	07/10/68	211FXHL	2,128	1,450	8.6	21.0	888	3	7	340	1.0	664	167	25	7.0	---	10.0	360	160
53N 70W 34DCC	07/10/68	211FXHL	2,700	1,550	8.6	16.0	978	2	0	370	1.1	597	259	37	3.3	---	11.0	540	120
53N 71W 12DD	06/30/68	125FRUN	780	1,300	8.8	13.0	820	3	1	320	2.1	729	117	6	2.3	---	9.4	140	110
53N 73W 12AB	05/14/68	111ALVM	108	935	7.8	13.0	566	19	9	205	6.1	604	7	11	.9	---	9.9	40	990
53N 73W 20BD	07/23/76	125FRUN	407	1,500	7.6	13.8	967	35	13	330	6.2	1,030	58	9	.8	.10	7.9	70	340
53N 73W 24AC	05/14/68	125FRUN	173	3,430	7.5	12.0	2,740	379	102	431	17.0	1,350	1,120	9	.7	---	7.6	30	580
53N 74W 07BCC	07/16/68	124WSTC	120	4,190	8.3	11.0	4,080	440	159	640	15.0	366	2,630	5	.1	---	9.6	100	2,600
53N 74W 35AB	07/22/76	125FRUN	210	3,750	7.4	12.5	3,220	300	130	480	9.8	259	2,100	6	.4	13.00	9.8	120	190
53N 75W 04AC	08/29/68	124WSTC	130	3,850	7.8	---	3,180	153	145	660	12.0	236	2,070	7	.3	---	3.3	60	20
53N 76W 22AB	07/12/76	124WSTC	1,050	1,260	8.0	25.3	891	7	3	350	7.2	970	15	18	1.1	.01	11.0	110	190
53N 76W 26AAA	07/17/68	125FRUN	1,043	1,840	8.8	21.0	1,160	22	10	440	14.0	1,304	0	13	1.3	---	15.0	110	1,400
54N 70W 09DCC	07/30/68	125FRUN	900	1,170	8.4	16.0	740	3	0	285	1.4	580	148	4	2.8	---	10.0	130	60
54N 70W 19DC	06/26/68	125FRUN	305	1,590	8.8	12.0	1,070	11	2	385	2.7	601	349	5	1.1	---	8.9	60	160
54N 71W 01CD	06/26/68	125FRUN	270	1,410	8.7	12.0	924	10	1	335	2.1	569	281	6	1.1	---	8.1	30	210
54N 71W 01CD	06/26/68	111ALVM	37	1,190	8.7	14.0	757	25	12	241	3.5	513	204	7	.8	---	8.6	60	120
55N 69W 35BB	07/30/68	125FRUN	320	2,230	8.3	10.0	1,650	145	92	280	9.0	652	781	14	.5	---	8.9	120	1,000
55N 70W 02ACC	07/18/68	125FRUN	555	1,430	8.5	14.0	932	4	1	340	1.7	536	306	5	1.6	---	8.2	240	90
55N 70W 14ADC	07/18/68	125FRUN	930	1,110	8.5	13.0	701	3	0	268	1.0	524	151	6	2.3	---	9.9	280	100
55N 71W 32BC	08/21/75	125FRUN	105	432	8.5	14.2	399	9	6	140	4.2	415	16	9	1.5	---	9.2	80	120
55N 72W 25CA	08/21/75	125FRUN	SPRING	217	7.8	15.2	209	36	12	14	8.6	177	24	3	.8	---	24.0	160	50
55N 72W 32CDD	07/31/68	111ALVM	60	1,520	8.4	9.0	992	35	40	262	18.0	709	258	13	.9	---	15.0	120	410
55N 73W 26	10/19/77	125FRUN	465	1,850	7.4	14.0	1,120	49	34	360	12.0	1,290	8	6	0.7	---	8.7	90	20
55N 75W 09BC	06/30/68	125FRUN	1,095	1,950	8.7	12.0	1,220	12	7	490	8.0	1,377	1	16	1.6	---	12.0	120	460
55N 75W 29BB	10/17/68	125FRUN	415	1,080	8.1	11.0	671	9	5	264	2.1	760	0	8	1.0	---	8.2	70	260
56N 70W 34BDA	07/18/68	125FRUN	580	1,230	8.5	14.0	792	3	1	300	1.5	539	206	6	.7	---	8.7	190	60
56N 71W 15DD	10/16/68	211FXHL	2,036	1,330	8.9	18.0	832	2	0	330	.6	669	130	26	4.5	---	9.0	440	180
56N 71W 30DBB	10/19/77	111ALVM	23	2,750	7.0	10.0	2,110	280	120	160	27.0	370	1,300	8	.6	---	30.0	500	120
56N 71W 30DBB	10/25/76	111ALVM	30	3,350	6.8	9.0	---	---	---	---	---	---	---	---	---	---	---	---	---
56N 71W 32BC	08/21/75	125FRUN	---	432	8.5	14.2	399	9	6	140	4.2	415	16	9	1.5	---	9.2	80	120
56N 72W 19CDC	10/29/76		SPRING	1,900	8.2	13.0	1,500	170	100	130	29.0	289	900	6	.4	---	17.0	1,200	30
56N 72W 21CCC	10/30/76	125FRUN	SPRING	530	7.8	9.0	402	68	26	19	14.0	216	140	3	.8	---	25.0	360	20
56N 72W 29ACC	10/30/76	125FRUN	280	2,350	7.4	6.0	2,030	260	130	140	27.0	106	1,400	4	.6	---	14.0	1,000	80
56N 72W 29ACC	10/30/76	125FRUN	SPRING	2,350	7.4	6.0	2,030	260	130	140	27.0	106	1,400	4	.6	---	14.0	1,000	80
56N 72W 30ABB	10/29/76		SPRING	2,600	6.7	11.0	2,270	250	140	, 220	24.0	423	1,400	8	.4	---	19.0	400	2,900
56N 72W 31DDA	10/25/76	125FRUN	683	1,325	7.1	9.5	891	33	19	260	10.0	542	290	8	.7	---	3.4	---	60
56N 72W 32AC	10/18/77	125FRUN	465	2,300	7.5	13.0	1,400	61	55	420	12.0	1,220	220	26	.7	---	6.3	80	320
56N 72W 33BCD	10/18/77	125FRUN	338	2,000	7.8	13.0	1,250	42	46	390	13.0	1,090	200	10	.7	---	8.0	90	50
56N 72W 34BD	08/21/75	125FRUN	SPRING	439	8.0	10.0	443	76	23	16	16.0	156	210	3	.8	---	21.0	530	40
56N 72W 36AB	08/21/75	125FRUN	SPRING	655	6.5	11.3	655	100	43	40	6.3	191	350	3	.8	---	16.0	410	1,900
	10/17/77	125FRUN	405	1,550	7.9	15.0	862	17	9	320	7.6	960	23	7	.5	---	4.6	90	210

Sample Location	Date of Collection	Aquifer	Well Depth or Interval sampled (feet)	Specific Conductance (microsiemens)	pH	Temperature (°C)	Dissolved Solids (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Alkalinity as bicarbonate (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Fluoride (mg/l)	Nitrate as nitrogen (mg/l)	Silica (mg/l)	Boron (µg/l[a])	Iron (µg/l[a])
56N 73W 25BBA	10/18/77	125FRUN	442	3,100	7.6	15.0	1,940	73	83	480	15.0	580	990	6	.2	---	1.7	100	60
56N 30W 25CC	10/17/77	125FRUN	422	2,050	7.2	10.5	1,280	37	27	450	8.2	1,410	48	5	1.0	---	8.0	90	170
56N 73W 25CC	10/26/76	125FRUN	175	2,210	7.6	10.0	1,740	62	42	520	11.0	1,250	480	5	.5	---	6.3	80	40
56N 73W 25CC	10/12/77	125FRUN	175	1,900	7.8	11.0	1,130	32	22	390	8.3	1,160	87	7	.9	---	7.8	80	110
56N 73W 27DDC	10/17/77	125FRUN	509	1,950	7.56	13.0	1,190	31	23	440	9.6	1,340	7	7	.6	---	7.9	100	60
56N 73W 29BDB	08/01/68	125FRUN	179	2,100	8.05	11.0	1,540	100	62	330	8.0	592	724	6	.4	---	11.0	80	1,000
56N 74W 04AA	08/11/76		---	1,750	8.4	41.5	1,080	1	0	440	2.1	1,121	20	40	6.6	---	17.0	370	40
56N 74W 04CB	08/11/76	125FRUN	3,850	1,750	8.4	41.5	1,330	1	0	450	2.1	1,609	24	41	6.5	---	17.0	380	40
56N 76W 25CB	07/08/76	125FRUN	850	3,800	7.5	16.0	2,060	26	18	800	12.0	2,330	24	21	.9	.02	9.0	160	160
57N 69W 25AAA	08/06/68	211PIRR	100	490	8.4	---	294	35	18	41	3.7	229	65	2	.5	---	15.0	20	150
57N 69W 26AC	08/06/68	211PIRR	180	866	7.9	12.0	554	81	38	52	7.4	353	183	2	.2	---	16.0	30	350
57N 70W 19DD	07/24/76	125FRUN	606	1,210	8.9	15.0	657	2	0	220	1.1	380	230	7	.5	.03	8.9	110	110
57N 70W 22DD	10/08/68	211FXHL	600	1,030	8.1	14.0	655	2	1	230	1.0	306	256	3	.3	---	11.0	60	20
57N 71W 14BD	08/06/68	125FRUN	615	1,060	8.8	13.0	661	2	1	254	1.1	521	129	5	2.3	---	9.6	130	150
57N 74W 08BA	07/09/76	125FRUN	212	1,920	7.2	12.5	1,210	16	9	470	5.7	1,370	11	9	1.0	.10	7.4	120	230
57N 74W 18DAA	08/01/68	125FRUN	400	5,890	8.3	13.0	5,620	444	319	890	21.0	753	3,560	10	.2	---	7.1	330	80
58N 69W 31CC	10/08/68	211FXHL	625	1,040	8.2	12.0	676	7	0	231	1.2	306	272	2	.1	---	11.0	30	40
58N 71W 25DC	09/24/68	111ALVM	18	4,190	7.9	---	3,460	225	129	712	21.0	688	1,980	25	.6	---	25.0	240	20
58N 71W 26DA	09/10/68	125FRUN	350	1,080	8.0	13.0	668	3	0	252	1.2	433	183	4	2.0	---	9.0	160	90
58N 73W 24DC	07/31/68	125FRUN	12	2,770	8.1	11.0	2,380	268	68	370	52.0	585	1,310	5	.8	---	18.0	5,400	50

[a]Concentrations in milligrams per liter (mg/l) or micrograms per liter (µg/l[a]) except as indicated; microsiemans per centimeter at 25 degrees Celsius.